AUTOMATION

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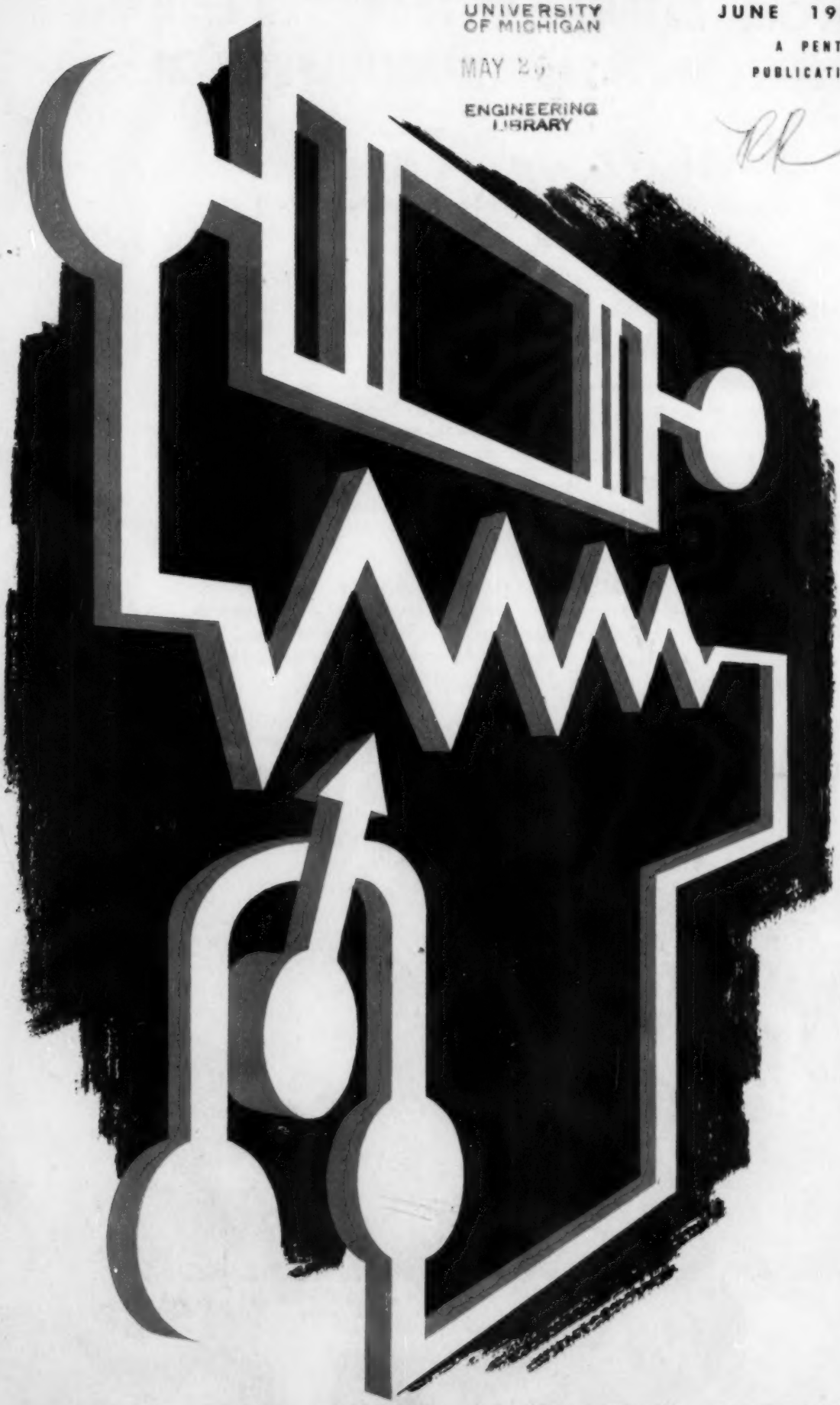


THE MAGAZINE OF AUTOMATIC OPERATIONS

WEAN "AUTOMATED" TRANS-CAR LINE SOLVES HEAVY PARTS HANDLING PROBLEM

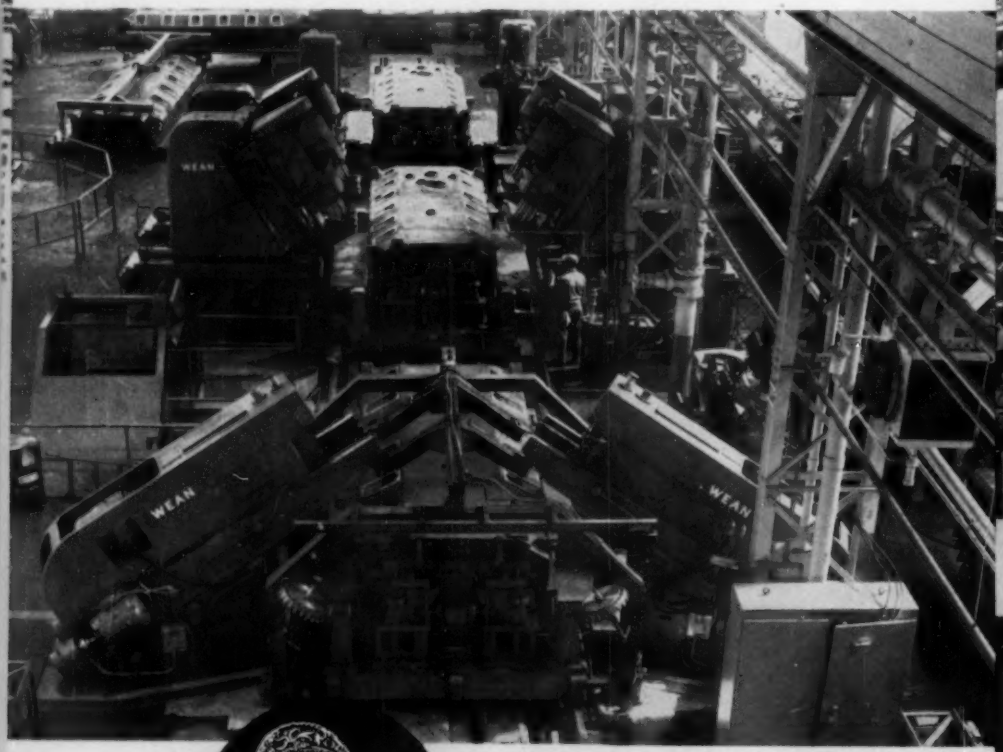
Unique system carries bulky sections through entire machining operation

The Massey-Harris Co. is used to handling and precision working large machine components. Thus, when they accepted the contract to produce combat vehicle hulls for the Army they immediately got in touch with Wean Equipment engineers.

A team of Wean Equipment engineers working with a similar group from Massey-Harris soon vetoed the possibility of using standard machine tools on a cost basis. It was decided a complete line, especially built to do the job, was the only practical answer.

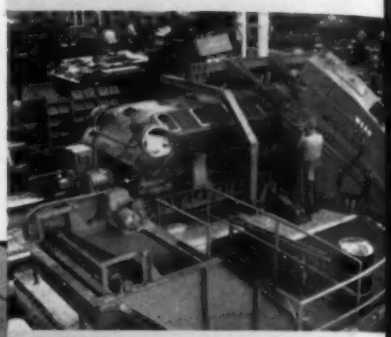
In eight months' time, Wean Equipment developed and built the now famous trans-car line. The line is composed of three stations: milling, drilling, and boring. The unusual feature is the car that operates on a set of tracks, running between stations, and eliminates all handling of the bulky, heavy hull.

If special "automated" machinery is what you're looking for, call in a Wean Equipment man today. He represents probably the widest experience in specialized machinery to be found anywhere. Like Massey-Harris, you'll find Wean the surest, most inexpensive way to soundly engineered, result-getting machinery.

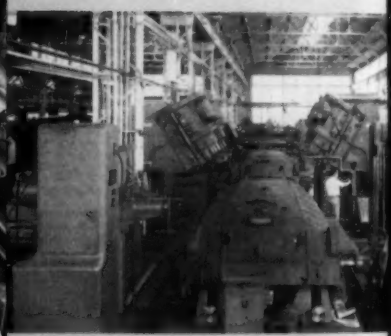


Over-all view of Wean Line that effected tremendous savings in producing giant hulls.

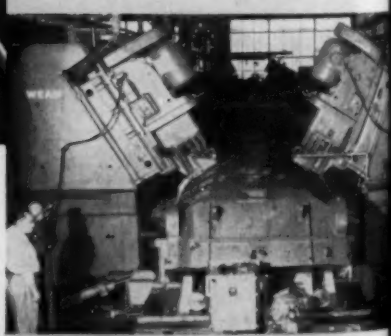
Unique trans-car that carries hull fr station to station.



Milling operation. Dry cutting w carbide cutters. Air jets remove ch



Drilling operation. Beneath the floo coolant system with magnetic ch separator.



Boring operation. Drills, taps reamers are of high speed steel. operations are automatic.

Wean

EQUIPMENT CORPORATION
CLEVELAND, OHIO

JUNE, 1955
Vol. 2—No. 6

AUTOMATION

THE MAGAZINE OF AUTOMATIC OPERATIONS

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automation outlook

THE GROWING PERIOD

". . . these long accepted features might be said to represent automation in its infant stage. Now in the period of adolescence, automation is represented by an integrated line of machines rather than a single automatic unit. The adult stage, yet to come, will probably be the automatic factory . . ."—*J. J. McCabe, The Heald Machine Co.*—*See Page 26.*

HYDRAULICALLY AND ELECTRICALLY CONTROLLED

". . . an outstanding instance (of the automatic factory) is the Ordnance Plant which Barnes set up. This plant uses special machine tools. It incorporates many special handling and conveying mechanisms. Most of these devices are hydraulically actuated. All are electrically controlled and, in many instances, several of them have their functions correlated by interrelated electrical controls . . ."—*W. F. & John Barnes Co.*

JUST TO STAND STILL

". . . to maintain present standards for the growing population, industry will have to raise production by an estimated 30 per cent within the next 10 years . . . The introduction of automatic machinery and improved methods should result in more than doubling present production by 1975 . . ."—*Industrial Relations News.*

UNDERSTANDING AND CONTROL

". . . automation is more than a manufacturing method or an economic necessity. It is a magic key to creation—to a better life for all of us. Like the atom, its potential is unlimited. But we must learn to understand it, control it and direct it into avenues of increasing human betterment. As we make our way toward that goal, it is the engineer who must spearhead our advance . . ."—*R. H. Sullivan, vice president and group executive, Ford Motor Co.*

PLANNING NOW FOR AUTOMATION

". . . as a result of the rapid technological developments being made, each company should determine now where it wants to be in the next five, ten, or more years, when machinery and equipment undreamed of today will be commonplace. Farsighted executives are planning right now for automation. Practically every company whose products can be produced by automation can afford it, because those companies are paying relatively higher manufacturing costs than would be incurred with automation . . ." —*C. E. Evanson, President, T.A.B. Engineers Inc.*—*See Page 39.*

A PROBLEM OF BRAINS

". . . automation is in essence the automatic performance of a control system by machinization instead of the human force, and includes automatic handling of materials from the raw material to the packaged item, —temperature, velocity, pressure, processing, assembly, receiving, storing, control and computing data, handling with cost accounting, etc. The base for all is the machine, mechanical and electronic, but it will *never* replace judgment. Thus we have a new labor problem in the demand for better experienced men . . ."—*Bernard Eichwald, Pres., B. Eichwald & Company, Inc.*

A TASK OF SELLING

". . . our major problem concerning automation does not appear to be so much the development of the machines to the job. Rather, it seems to be the task of convincing our employees and the general public that the acceptance of this mechanical approach is to their benefit rather than to their detriment. Increasing ability to produce in quantity opens more vistas and provides growth and security for the individual and the nation. To maintain or improve our standard of living in the future we must obviously multiply our ability to utilize the resources available to use . . ." —*John N. Hart, director of employee relations for The B. F. Goodrich Co.*

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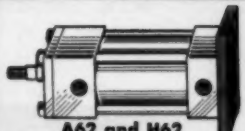
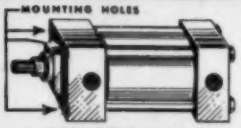
"IN-STOCK" MODELS

"A" Signifies Miller 200 psi Air Cylinders; "H", 2000 psi Hydraulic Cylinders. Interchangeable Mountings Are Shown In Red On Drawings.

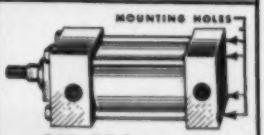
A61 and H61
Flange Mounting on Rod End
(A61 not available in 8" bore)



A62 and H62
Flange Mounting on Cap End
(A62 not available in 8" bore)

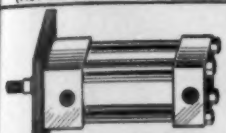


A63—8" Bore only
Flange Mounting on Rod End

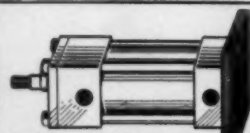


A64—8" Bore only
Flange Mounting on Cap End

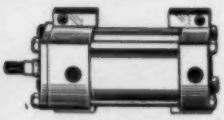
A50 & H50—Tie Rods not extended beyond nuts.
A51 & H51—Tie Rods extended both ends (shown).
A52 & H52—Tie Rods extended. Cap End only.
A53 & H53—Tie Rods Extended. Rod End only.
A54 & H54—Two Tie Rods extended at both ends.



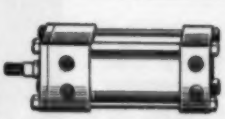
H65—Hydraulic Only
Flange Mounting on Rod End



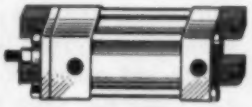
H66—Hydraulic Only
Flange Mounting on Cap End



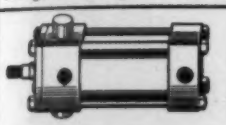
A72 and H72
Side Lug Mounting



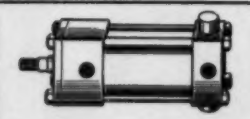
A74 and H74
Side Flush Mounting



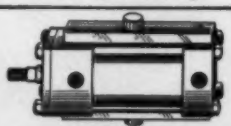
A77 and H77
Side or Foot Mounting



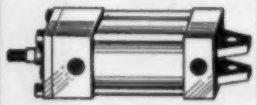
A81 and H81 Trunnion Mounting on Rod End



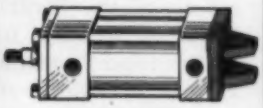
A82 and H82 Trunnion Mounting on Cap End



A83 and H83 Trunnion between Head and Cap (one week delivery)



A84 and H84
Pivot Mounting



A86 and H86
Pivot Mounting

IN STOCK BORES in Inches

	BORES	ROD DIA.	ROD TURN DOWN & THREADS	"IN-STOCK" STROKES (in Inches)																				
AIR	1½	⅝"	7/16-20	Cushioned			3	4	5	6	7	8	9	10	11	12								
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12								
	2	⅝"	7/16-20	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	2½	⅝"	7/16-20	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	3¼	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	4	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	5	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	6	1⅜"	1-14	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	8	1⅜"	1-14	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
HYDRAULIC	1½	⅝"	7/16-20	Cushioned			3	4	5	6	7	8	9	10	11	12									
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12									
	2	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	2½	1"	¾-16	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	3¼	1⅜"	1-14	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	4	1¾"	1¼-12	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
	5	2"	1½-12	Cushioned			3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36
				Non-Cush.	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	28	32	36

① "A" and "H" Models 82, 84 and 86 with strokes over 18" require stop tubes.

Column strength requires larger diameter piston rods for the following:

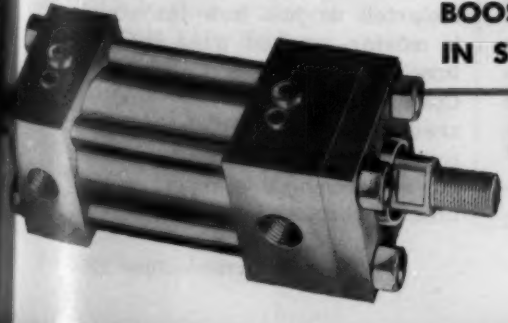
Air Cylinder Models A82, 84, and 86 with strokes inside area (1), when operated at 100 psi and over;

All hydraulic models with strokes inside area (2) and Models H82, 84, and 86 with strokes in area (4), when operated at 2000 psi and over;

Models H82, 84 and 86 with strokes inside area (3), when operated at 1000 psi and over.

Depending upon Trunnion Pin location, "A" and "H" Models 83 with standard diameter piston rods can have longer strokes than Models 82, 84 and 86.

See Miller File #251 for oversize piston rod and stop tube requirements.



BOOSTERS IN STOCK

Immediate Delivery on the following Miller 25 to 1 Ratio Boosters (80 psi air input produces 2000 psi hydraulic oil output): Model B4, 5" bore, 1" dia. ram, 6" and 12" strokes; Reciprocating Booster Model DA77-RBAB, 5" bore, 1" dia. ram, 6" stroke. Also Booster Tanks, 5" dia., 6" and 10" heights.

Write For Catalog and Stock Price List

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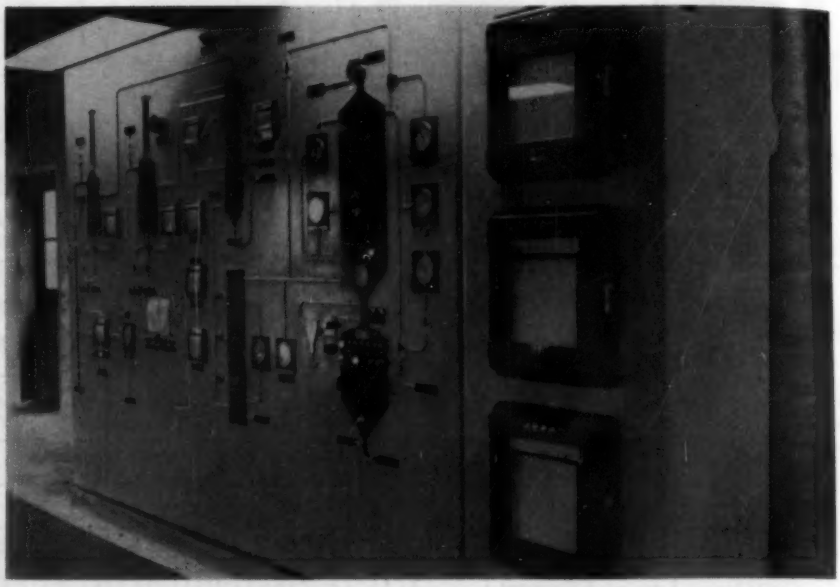
AIR & HYDRAULIC CYLINDERS • BOOSTERS • ACCUMULATORS
COUNTERBALANCE CYLINDERS

AUTOMATION news

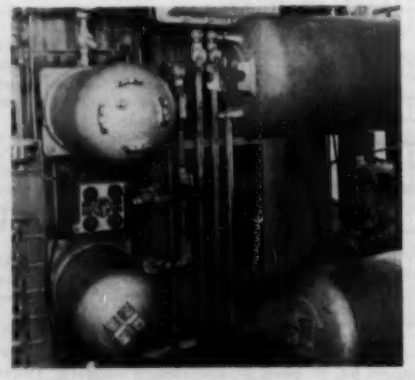
Today's events and developments in the field of automation

Continuous Analyzers Indicate Stream Composition

SUCCESSFUL use of continuous infrared analyzers to control the purity and output of a petrochemical plant has been announced by **Dr. Van Zandt Williams**, vice president and director of sales and research of the Perkin-Elmer Corp. Units are installed in a new plant of American Cyanamid Co. producing acrylonitrile, a chemical building block used principally in the manufacture of synthetic fibers and rubber. "Continuous analytical instruments such as tri-non analyzers," Dr. Williams stated in announcing the installation, "help close the loop between a chemical product and the environment in which it is made, and bring us closer to the day of the automatic factory. They represent a new concept in chemical plant operation—that of control by stream composition rather than stream environment." These instruments enable plant operators to know exactly, at any moment, what the composition of the product stream is. If the analyzers show that stream composition is not at maximum efficiency, changes can be made immediately—before permanent damage is done to the equipment, or before any substantial amount of substandard product is allowed to get through. Conventional analytical methods take hours to do the same job and this time lag can result in serious dollars and cents losses if the process stream is not functioning normally.



RECORDERS on control panel of the acetylene unit at new petrochemical plant of American Cyanamid Co. show concentration of the gas under analysis by infrared analyzers manufactured by the Perkin-Elmer Corp. Lights on the recorders indicate exact unit being sampled. If concentration falls below a critical point, corrections can be made before a dangerous situation develops or before large quantities of below standard product flow through the processing lines.



INFRARED analyzers are used to monitor acetylene and methane in the product stream. These instruments, through control board, enable plant operators to know exact composition of the product stream. Infrared analysis is based upon characteristic absorption of particular wavelengths of infrared energy by organic material.

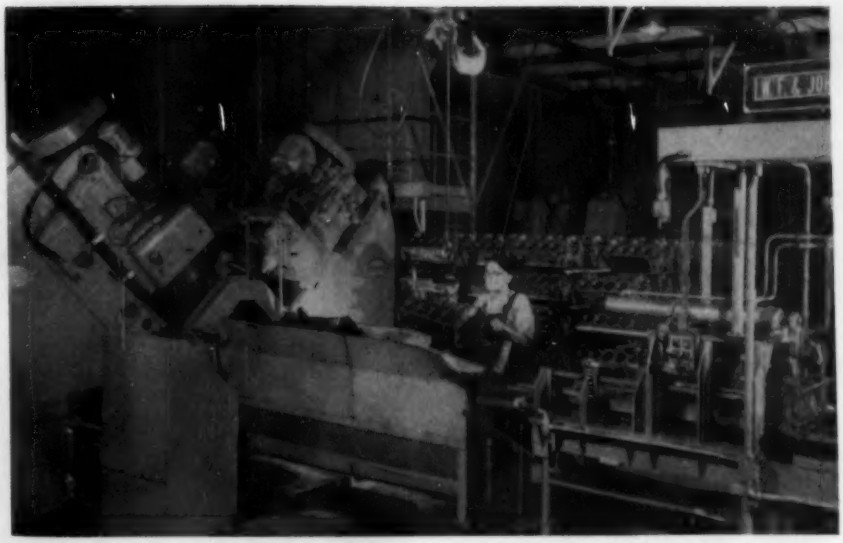
Acrylonitrile is made by reacting hydrogen cyanide with acetylene. The unique acetylene process is a highly critical one, demanding precise operating conditions for maximum yield, and to ward off danger of explosion. For these reasons, the plant designers realized that conventional controls of pressure, flow rate and temperature were not adequate to keep plant operators apprised of the exact status of the process stream. In other words, conventional controls tell us just how the stream is moving—and at what temperature, but not what is *in* the stream. Conventional laboratory analyses are very costly to maintain on a round-the-clock basis and are often not rapid enough to report in safe time on explosive conditions that

might develop.

Several analyzers have been installed at the Cyanamid plant. One pair is mounted near each of the two groups of four burners. One analyzer in each pair determines methane concentration and the other, acetylene. An automatic sampling system successively admits a small portion of gas from each of the burners into the analyzers and the results are recorded on a chart for each analyzer in a control room two floors below. Sample cycling time is 8 minutes for 4 burners.

Additional analyzers are installed in an ammonia unit. One of their most important tasks is to check on the concentration of oxygen containing compounds in the feed streams to the ammonia reactor. Such compounds would quickly poison the catalyst were they allowed to reach the reactor.

These analyzers respond faster, require less attention than other analytical methods, and give ample warning of any dangerous situations developing in the process. As a result, they permit operation of the plant much closer to safety limits, resulting in an increased throughput.



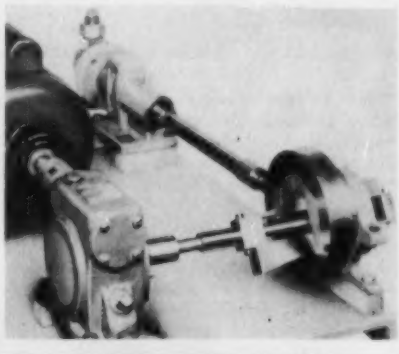
AN EXAMPLE of the segmented feature of the production line at the Chevrolet V8 engine plant. In the background is a "bank" of blocks which have been machined up to this point, having passed through the W. F. & John Barnes transfer unit, its last station on the right. The operator is demonstrating how a block is moved from the bank to the conveyor, to continue its travels through the next transfer machine. There are nine such "breaks" on the 320-foot line, each one available in case the transfer machine behind the bank is shut down for one reason or another. When three additional production lines have been installed, it will be possible to move parts from one line to another, thus maintaining a steady movement of stock.

TALK entitled "Automation — the New Technology" was delivered before the New England Congress of the National Metal Trades Association by **Milton O. Cross Jr.**, pres-

ident of the Cross Co., one of the nation's leading producers of machine tools. He declared, "Automation is an economic necessity to America during the next 25 years and must be adopted at every opportunity because of the more educated and mature populace which will come into existence in that time. This better educated population will experience a very acute shortage of labor, which will have to be filled, and can only be filled by automation." While touching briefly on some aspects of automation in the machine tool field, Cross, talking on a much broader scope, discussed the impact of this industrial method on management techniques in planning, finance, administration, execution and personnel relations. He described briefly what he considers to be the three natural divisions for the application of automation, namely, the fabricating industries, processing industries and the field of statistical data, including communications.

Truck Distributors Association

GROUP of New England materials handling distributors have recently formally incorporated under the name of Associated Equipment Distributors Inc. to establish a code of ethics and expand the interests of their group with customers and suppliers. The president is **C. C. Haddrell** of Lee H. Long Associates; vice president, **Clem Williams** of Brodie Industrial Trucks; and treasurer **William Paul** of Kinco Inc. The directors are **H. A. Ireland** of the H. G. Davis Co.; **Paul R. GrosJean** of New England Industrial Truck, and **John Mitchell** of Field Machinery. The majority of indus-

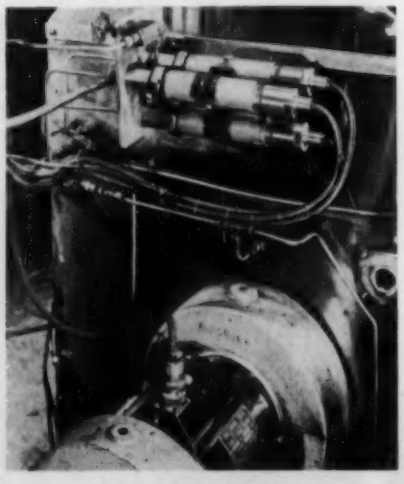


STEPLESS adjustment of proportioning pump capacity utilizes wedge to obtain variable piston stroke. Device patented by Philadelphia Pump & Machinery Co. is a link between a proportioning pump and control motivating equipment—whether manual, hydraulic, pneumatic or electric—for adjustment of pump capacity while running to accomplish accurate metering in relation to some meterable factor. Movement of wedge through a slot in a cam varies eccentricity of the cam permitting stepless adjustment from zero to maximum piston stroke.

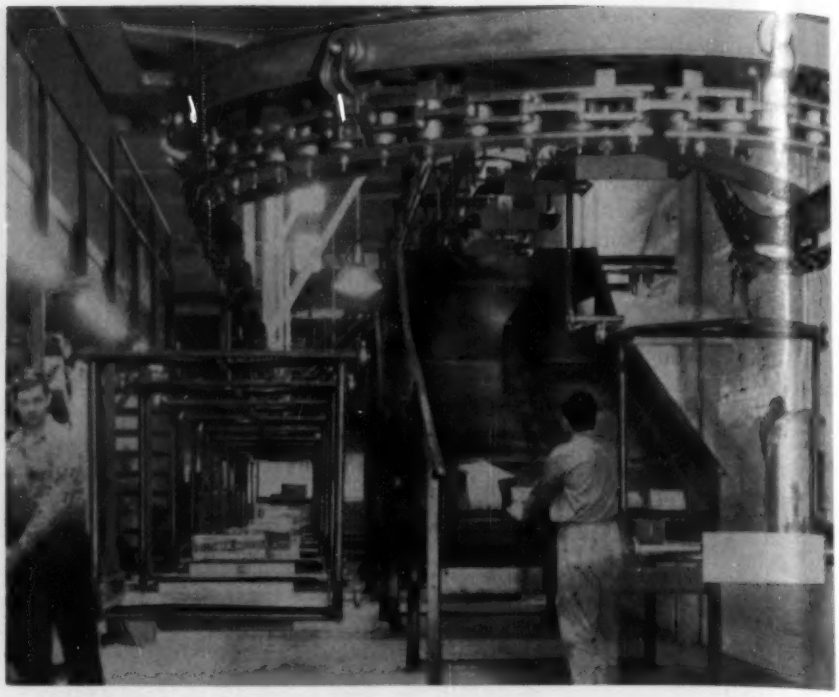
trial truck distributors in this territory are members and the membership is being expanded to include distributors in other fields of materials handling equipment.

Apprentice Training Conferences

SECRETARY OF LABOR **James P. Mitchell** today announced a series of multi-State conferences on apprentice training "to tackle some of the problems posed by the shortage of skilled workers in the Nation." An Eastern Seaboard conference will meet May 31 to June 2 at the Concord Hotel, Kiamesha Lake, Monticello, N. Y. Also scheduled is a national meeting July 5-8 at Old Point Comfort, Va., and a Southern States conference September 29-October 1 in Oklahoma City, Okla. Plans are being completed for the first multi-State apprenticeship conference in the Midwest, to be held in Indiana. Mr. Mitchell said "the need to raise the level of skills of the American work force is urgent. Major trends and economic projections indicate that within the next 10 years training will have to be increased tremendously in quantity and improved greatly in quality. These trends include increased technological development in both industry and the armed forces as well as rising production. The conferences are sponsored by labor and management with the assistance of State apprenticeship agencies and the U.S. Labor Department's Bureau of Apprenticeship.



THREE Baldwin pressure cells and a torque pickup (below) of 30,000 in.-lb capacity electrically feed recorders that plot performance curves during a 3½-second test of new turbine-type fuel-air combustion starters for jet engines. Resistance-wire strain gages in these devices transmit to centralized recorders electrical pulses that measure variations of starter torque, combustion chamber pressure, fuel pressure and air pressure. Starter being tested is mounted on other side of the metal panel.



PROTOTYPE of the key components of a Kidde automated warehousing system has been built in co-operation with Link Belt Co. and The Teleregister Corp. System operates on principle of bulk picking. Items in any one area are picked at same time and placed on individual conveyor trays; at another point controls are activated which schedule the discharge of all items of one order at predetermined chutes assigned to specific customers. The Kidde system is important to any industry or business which must warehouse and distribute case and broken lots of a wide variety of products.

Electronics for Defense Depend on Automation

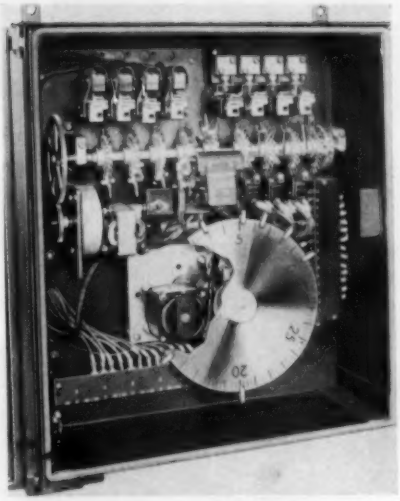
COMPLETION of the Signal Corps' electronic automatic component assembly system being built by General Electric Co.'s electronic division is scheduled for late summer. Operation details of the system have been described by **Dr. W. R. G. Baker,** General Electric vice president and general manager of the electronics division. He said the system will be programmed by groups of punched cards, similar to those in common use for business records. When a different type of equipment is to be assembled, the operator need only insert the group of cards for that particular operation. The cards will be rapidly checked by an electronic reader which then will feed the production steps to the various units of the system. The system then sets itself up to prepare and test components, convey them to the assembly unit, assemble them, solder them, and test the complete workpieces. The completed system will be able to insert about 1600 components per hour for an average production of about 50 completed units per hour.

Dr. Baker noted that other types of automatic component placement systems for electronic equipment are in use or in development, but that these primarily are designed for mass production runs on such equipment as home radios or TV sets. Military electronic equipment, however, is produced in considerably smaller volume, with most of it made in lots of a thousand or less. This requirement means that any system to assemble military electronic equipment must be highly flexible and capable of rapid

changeover for production on varied types of equipment. **Brig. Gen. Herbert L. Scofield,** chief of the Signal Corps Procurement and Distribution Div., in describing the importance of the new system said, "The Signal Corps, in co-operation with the electronics industry, has been working for a long time on ways to increase production of communications and electronic equipment for war requirements. With the completion of a fully automatic component assembly system capable of handling all types of military electronic equipment, we will have overcome many of our production problems. Human errors in production are a plague in time of warfare. As much as 20 per cent of a day's output of radios, walkie-talkies, and other electronic communications devices were rejected by the military services during World War II because of human failure. The solution to this problem lies in the Automatic Component Assembly System."

FORMERLY executive vice president, **Douglas C. Lynch** has been named president of Brush Elec-

tronics Co. Appointment was announced by **W. Russell Burwell,** vice chairman of Clevite Corp. and former president of Brush Electronics, a major unit of the Clevite Corp. Lynch joined the company in 1952, having previously been head of the international operations of Crosley Div. of AVCO Mfg. Corp., and later a senior staff executive of Willys-Overland Motors Inc. His background includes service with Westinghouse Electric Corp. in a number of engineering, sales and management positions. He served as assistant general manager of Westinghouse International. Brush Electronics manufactures electronic instruments and is a large producer of magnetic recording heads and piezoelectric crystals. It is the second largest unit in the Clevite group of companies, which includes the Cleveland Graphite Bronze Co., Harris Products Co., Clevite Ltd., and Transistor Products Inc.



PRECISE timing and co-ordination of batch processes are facilitated by use of timed-program controller developed by Taylor Instrument Companies. Unit consists of motor driven time measuring device and an independently driven step disk mechanism controlling the operation of from one to eight electric or pneumatically operated functions. Time settings are made directly on time scale and step disk mechanism.

Controlled Brilliance

STABILIZED light source whose brilliance does not vary more than 0.01 per cent has been developed by Ransom Research. The new device which operates from conventional house current is intended for use in laboratories as well as in military and industrial applications where a constant light source is required as a reference. Transistors and saturable transformers are used in the device to automatically regulate the flow of current through a lamp to maintain constant filament temperature and current. Minute changes in the filament voltage are immediately detected and corrected by the control amplifier. A long-life mercury battery is used as a reference by the control amplifier.

Look for Improved Photo Processing

NEW ACTIVITY, which will concentrate on design, research and production of special, rapid film processing equipment for military and commercial application has been activated by Fairchild Camera & Instrument Corp. according to an announcement by **John M. Case,** executive vice president. To be known as the Processing Equip-

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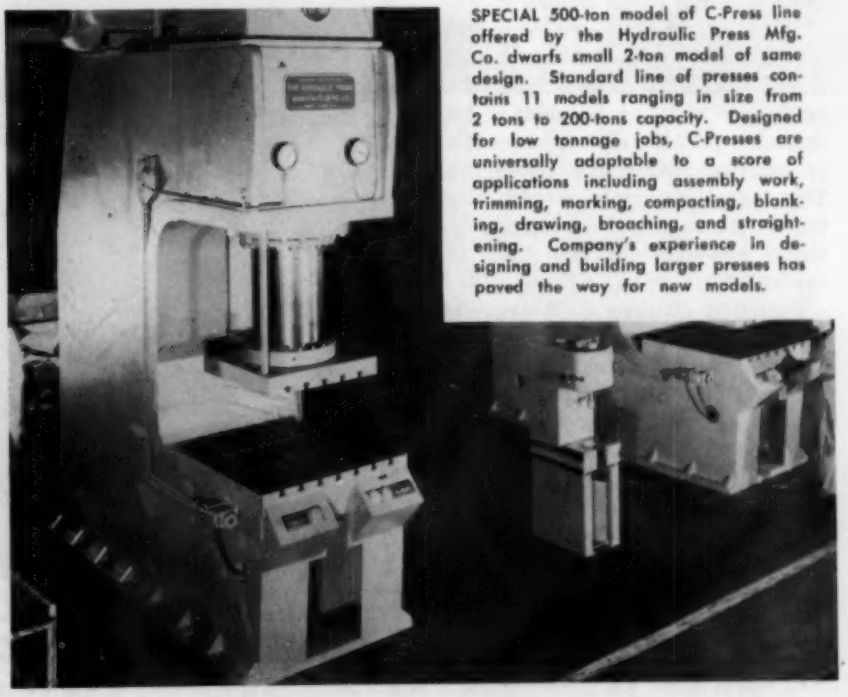


SPECIAL 500-ton model of C-Press line offered by the Hydraulic Press Mfg. Co. dwarfs small 2-ton model of same design. Standard line of presses contains 11 models ranging in size from 2 tons to 200-tons capacity. Designed for low tonnage jobs, C-Presses are universally adaptable to a score of applications including assembly work, trimming, marking, compacting, blanking, drawing, broaching, and straightening. Company's experience in designing and building larger presses has paved the way for new models.

ment Section, the new activity will be under the direction of **Charles N. Edwards,** formerly chief engineer of Fairchild's Systems Div. Affiliated with Edwards as research associate will be **Joseph A. Schantz,** who comes to Fairchild from the Naval Photographic Center where he was head of the methods and processing division. A photo-chemist, Schantz is well known in the field of rapid film processing. "The past 3 years have witnessed a tremendous increase of military and commercial interest in specialized photo processing equipment, particularly rapid and airborne processing techniques," Edwards commented. "Through the use of these techniques the overall size and complexity of continuous film processing machinery can be markedly reduced. The new section has the objective of making photographic and other allied processing equipment a real portion of the company's business." While initial activities will be directed towards airborne and field processing equipment, a wide scope of military and commercial applications are envisioned. Industrial advantages offered by the new organization will be in regard to simplification of the photo developing process. "The scientist or technician will be able to process his own recording and instrumentation films in seconds. The undeveloped film need no longer wait, or be shelved for extended periods, due to some other priority within the photo lab. This same principle would hold true in the rapid processing of television, newsreel and new film," he explained.

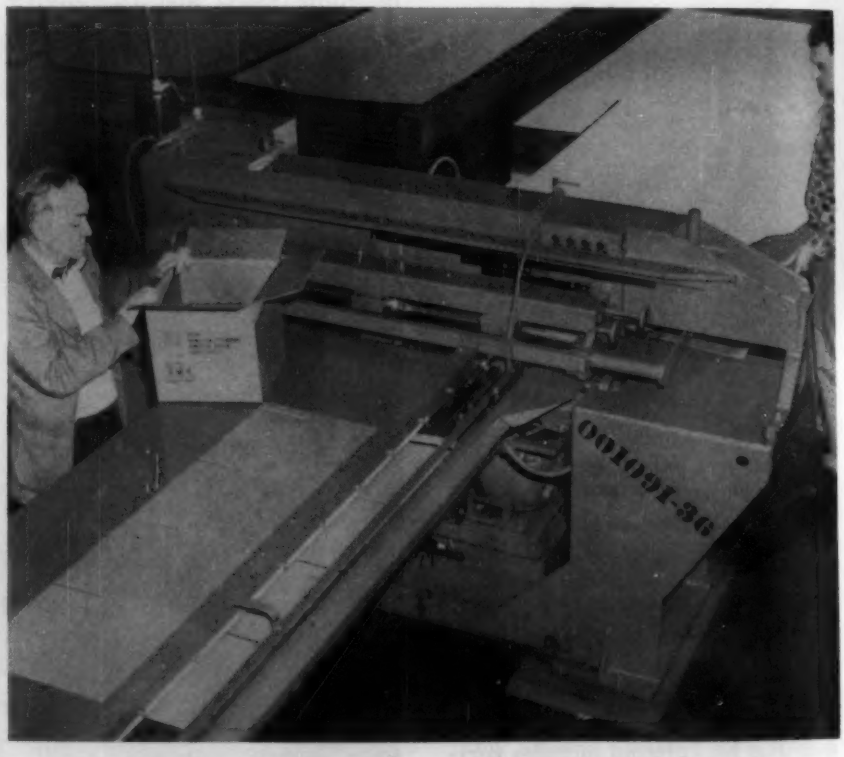
Fairchild Camera & Instrument Corp. has also announced through **John H. Clough,** president, that all voting stock of the Freed Electronics & Control Corp. has been acquired and hereafter Freed Corp. will operate as a subsidiary of Fairchild. "By this acquisition, Fairchild gains 35 years of electronic experience of the Freed Corp. together with a background position in ultrasonic display, storage and recording techniques as applied to radar photography and mapping in which Freed has recently specialized," Mr. Clough commented.

POSITION has been established by the Swartwout Co. to provide unified supervision of the company's three divisions. Swartwout Co. is a pioneer producer of all-electronic controls for the chemical process and petroleum refinery industries. **Joseph P. Green** has been appointed

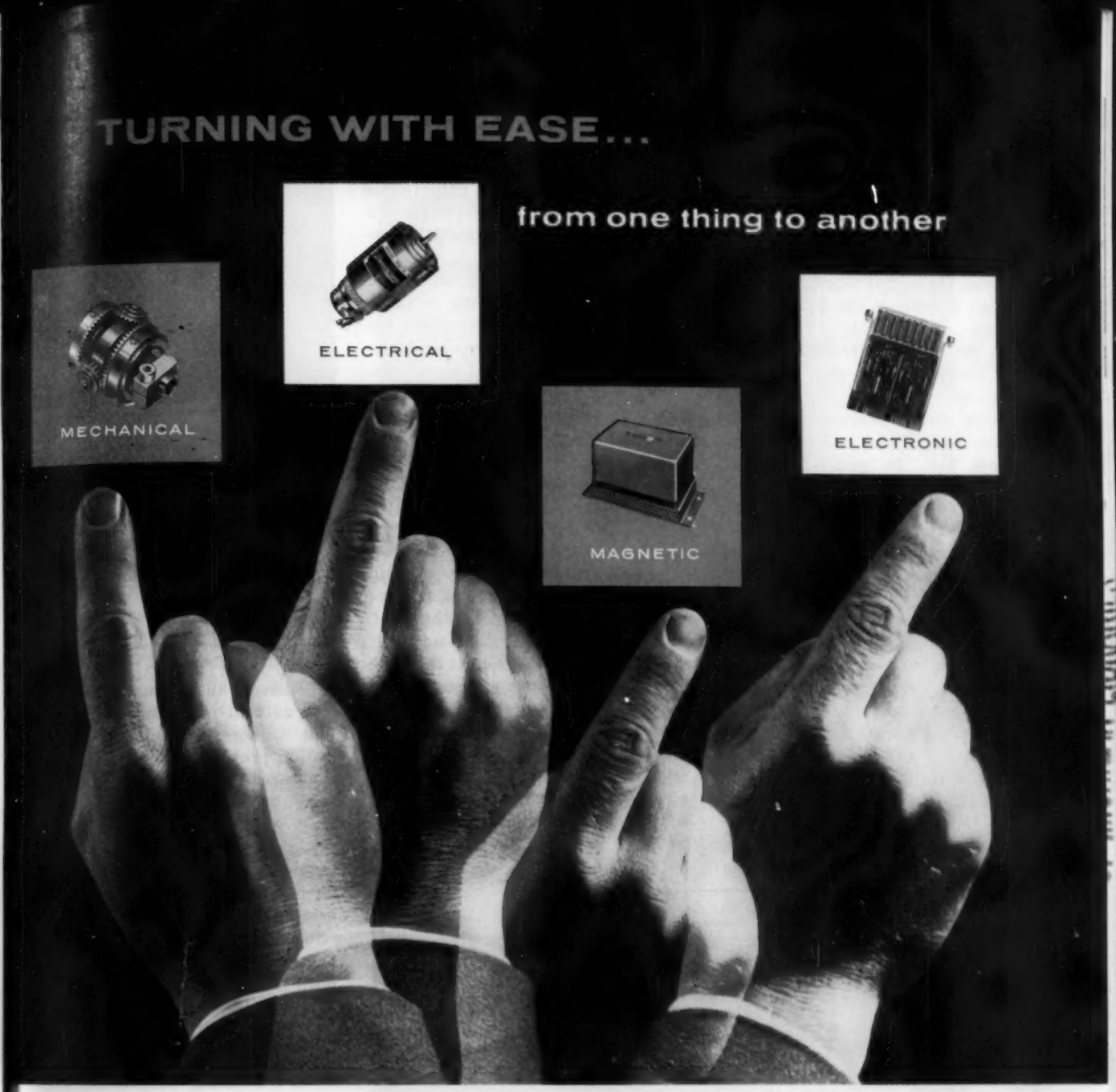
director of engineering to fill the position. Prior to joining the Swartwout Co., Green was associated with the H. K. Ferguson Co. as chief instrument engineer, Bailey Meter Co. as supervisor in sales engineering and the General Electric Co. He is an active member of the Instrument Society of America, American Institute of Electrical Engineers and the Cleveland Engineering Society.

Sacrifice Styling for Machine Performance

TOOLING-UP PROGRAMS in most American industries are almost never of a permanent nature, the chief production engineer of Pratt & Whitney Aircraft Corp., **E. P. Bullard III,** declared at New York University before the 1955 Machine Design division conference of the American Society of Mechanical Engineers. In some cases, such as in the styling of automobile bodies, "there are strong indications that changes are sometimes made simply for their own sake, inasmuch as the public tends to become tired of an old product." The more unskilled and semi-skilled labor that



NEW MACHINE, produced by Colt's Mfg. Co. for Hamilton Standard Div. of United Aircraft Corp., makes it possible to produce various styles and sizes of cartons from corrugated sheets. The machine performs the necessary operations of slitting, slotting, scoring and cutting-off automatically. Simple controls enable an operator to make complete dimensional changes in less than 1½-minutes. It is possible to produce exactly the right kind of carton for each item to be packed when it is needed and in the required quantity.



One standard to follow in selecting a designer for your specialized electronic control systems is to choose a firm that builds its *own* components for the control systems it makes. Librascope, Inc. manufactures such diverse electronic components as read-record heads, drums, magnetic amplifiers, flip-flop cards, packaged circuitry, analog-digital converters and other devices for sub-assemblies in its own military and commercial systems packages. This versatility of "turning with ease from one thing to another" indicates a competence for overall systems design acquired through nearly two decades in computer-control manufacture. Such highly specialized experience is available for the solution of your data-handling or computer control project. Inquire today.

Librascope also manufactures mechanical and optical components for computers and controls. Send for booklet describing the company.

Engineers in search of interesting assignments, security, advancement—contact Mac McKeague, Personnel Director.

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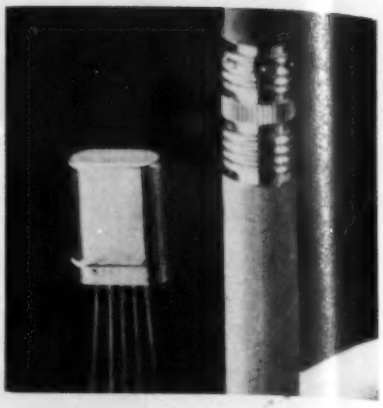
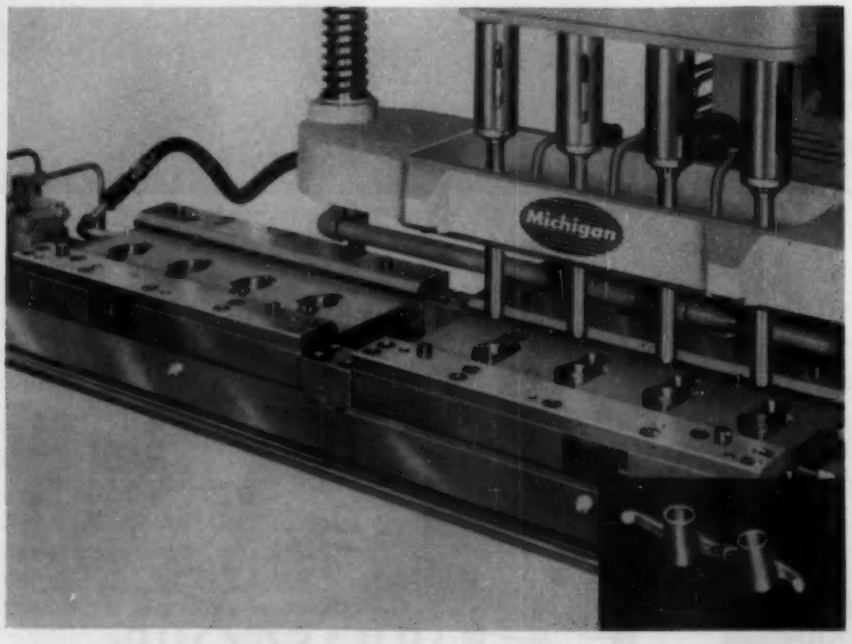
is used, the greater the need for special tooling. Old-time craftsmen were able to produce almost any product with a very few fundamental tools, but these tools are almost useless in the hands of the novice. Consequently, it is necessary that the tools supply the need, skill and knowledge which the novice lacks."

Since design accounts for about 10 per cent of the cost of building a new tool, he pointed out, designers can make considerable savings in overall costs by increased attention to traditional design considerations. He listed these as simplicity, actual use of equipment, adaptability to manufacture by general purpose rather than special equipment, economy in materials, and use of standard commercial elements and scrap material. Other considerations he cited are maximum use of standard dimensions, incorporation of simplified means of inspection in the part, and ease of handling and assembly. Much unnecessary expense can be avoided if the designer visualizes the manufacture of each part as he draws it. Unusual shapes, such as ellipses, compound angles, and nonconventional forms, are almost always difficult and expensive to produce. It is perhaps unfortunate that the draftsman is supplied with French curves and drafting machines.

B. D. Smith, general supervisor of mechanical engineering research for International Harvester Co. predicted that attractiveness probably will not be a feature of machine tools in the age of automation. "With the advent of automation there is now a tendency for industrial users to sacrifice styling and place more emphasis on machine performance, work handling, safety, and maintenance." Until recently, engineers and buyers insisted on streamlining and styling in machine tools. With increasing use of automatic machinery, he said, this inclination does not lend itself to economical and efficient machine tool design. This is but one of the implications of increased mechanization of industry, Mr. Smith stated. He also cited low production—production of parts in relatively small numbers. Designers of tomorrow's machines will have to build versatility into machines, he said, in order to amortize more expensive automatic machinery. The natural reluctance of machine tool builders to work out mechanization problems in limited production areas must be overcome, he said, but much of the initiative must stem from the end product manufacturer. Larger machine tool builders concentrate on high production, and smaller builders "are hesitant to risk costly engineering effort in low production areas without the assurance of financial support."



SMALL shock resistant relay has been developed by Elgin-Neomatic Inc. Relay is housed in a standard transistor case and is described as an example of how Elgin is applying the watch manufacturer's high precision mechanical skills to miniaturization problems in the electronics field. The "neomite" is a single-pole double-throw relay weighing 0.035-oz. It is rated at ¼-amp, 26.5 volt dc and requires 100 milliwatts for closure.



AUTOMATIC two-station shuttle fixture has been designed by Michigan Drill Head Co. for reaming of rocker arms. Fixture provides for automatic ejection of finished work into tote pans. Interchangeable nesting plates, for any size or shape rocker arm, will fit the fixture. With the use of the fixture it is possible to ream to a finish of between 20 and 30 microinches, eliminating the need for further super finishing.

MEETINGS AND EVENTS

June 7-10—

American Welding Society. National spring meeting and exposition to be held Hotel Muehlebach and Municipal Auditorium, Kansas City, Mo. Additional information may be obtained from society headquarters, 33 W. 39th St., New York, N. Y.

June 14-16—

American Institute of Electrical Engineers, American Physical Society and American Institute of Mining and Metallurgical Engineers. Joint conference and exhibit on magnetism to be held William Penn Hotel, Pittsburgh. Additional information may be obtained from A. C. Beiler, Westing-

house Electric Corp., 2-F Materials Engineering Dept., East Pittsburgh, Pa.

June 16-17—

Machinery and Allied Products Institute. Annual meeting to be held Statler Hotel, Washington. Additional information may be obtained from institute headquarters, 120 S. LaSalle St., Chicago 3, Ill.

June 20-23—

American Electroplaters' Society. Annual meeting and exhibit to be held Public Auditorium, Cleveland. Additional information may be obtained from exposition headquarters, 1849 W. 24th St., Cleveland 13, Ohio.

July 12-14—

Western Plant Maintenance & Engineering Show. To be held Pan Pacific Auditorium, Los Angeles, Calif. Additional information may be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Aug. 15-17—

Society of Automotive Engineers. Golden Anniversary West Coast meeting. To be held Hotel Multnomah, Portland, Oregon. Additional information may be obtained from society headquarters, 29 W. 39th St., New York 18, N. Y.

Aug. 22-23—

National Industrial Conference Board. Electronics and automation symposium jointly sponsored by Standard Research Institute to be held San Francisco. Additional information may be obtained from NICB headquarters, 247 Park Ave., New York, N. Y.

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Model DS-8600 Series (5 Models)

Designed to control any operation after a preselected total count has been reached. Used to count pills, bottles, cans, machine parts, etc. for automatic packaging. If an event can be converted to an electrical impulse—it can be counted and controlled with a Detectron Preset Counter. Dual models available which provide output signals at any two preset totals. Write for catalog or contact nearest representative.

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SPECIFICATIONS	DS-8602	DS-8603	DS-8604	DS-8605	DS-8606
Decades	2	3	4	5	6
Count Capacity	100	1000	10,000	100,000	1,000,000
Counts Per Second	0-100,000				
Input Sensitivity	0-10 counts per second: 1 volt RMS 10-20 counts per second: 0.5 volt RMS 20-100,000 counts per second: 0.1 volt RMS				
Input Impedance	1 megohm., 0.05 mf.				
Output Signal	50 volt positive pulse				
Recycling Rate	35,000 per second				
Hold Time	Automatic: 0.01 to 0.1 seconds 0.1 to 1.0 seconds 1.0 to 10 seconds			Manual: Until reset	
Power Requirements	117 volts ± 10%, 50-60 cycles				

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By FLOYD G. LAWRENCE, Detroit Editor

PARSIMONIOUS AUTOMATION

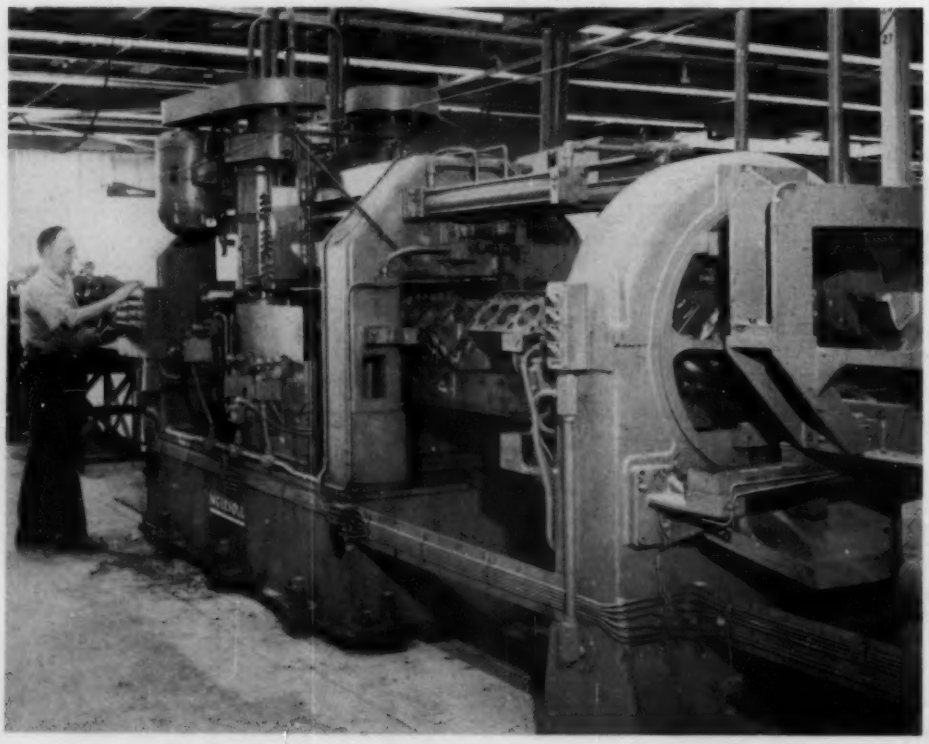
WHEN IT comes to automation, many observers figure the independent auto companies have a built-in handicap owing to their limited volume. But the new Utica, Mich. engine plant of Packard proves that the solenoids click for the small fry as well as for the millionish producers.

Ray P. Powers, manufacturing vice president, describes the difference as one of capacity but not efficiency. For in the Packard engine line, no duplicate tools are used to balance capacity as in the larger engine lines. Drilling cylinder head stud holes requires several passes for most firms, for example. Packard drills the holes in one pass.

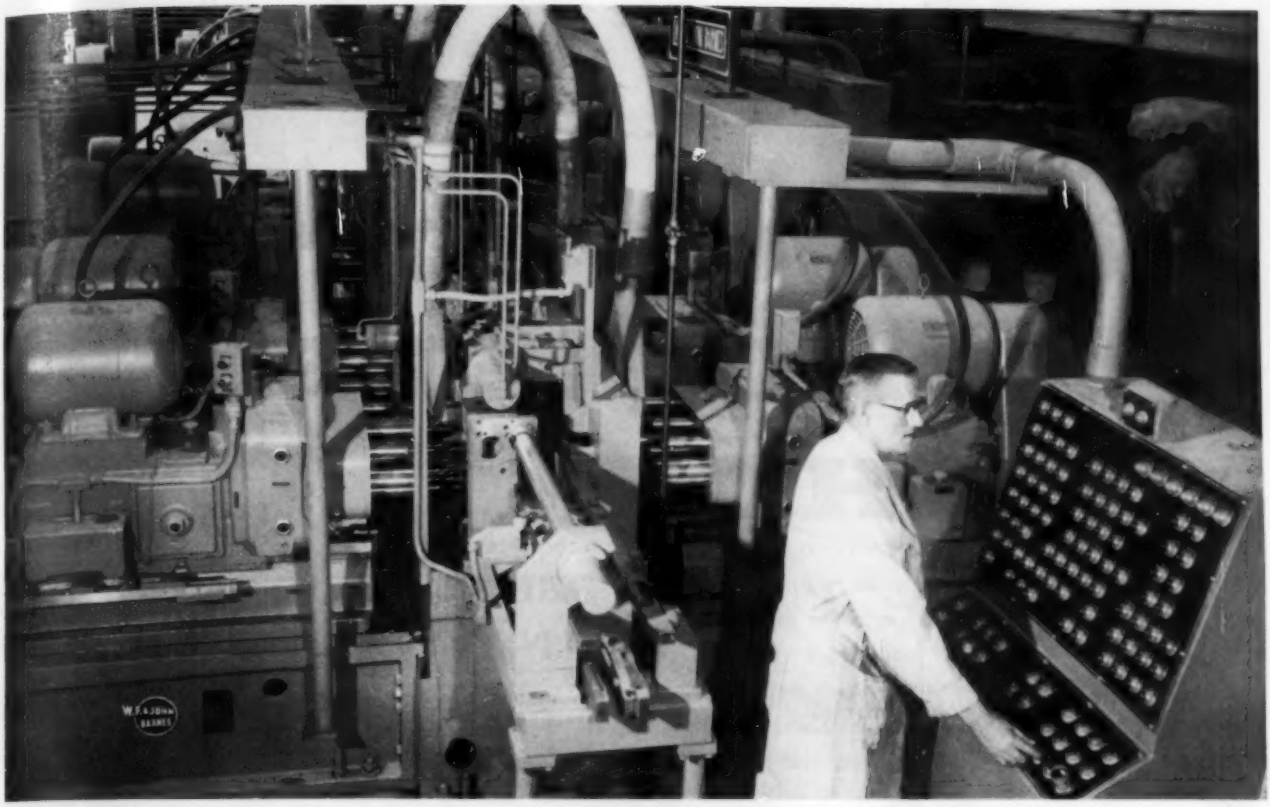
That means fewer drilling heads, tools, controls and less maintenance. Also saved is plant space, with the Packard block line stretching only 800 feet in contrast to the Ford block line in Cleveland which stretches 1545 feet.

The procedure in setting up the Packard line was to determine the longest single operation in establishing the basic cycle time to produce 100,000 units annually on single shift operation. Equipment for the other stations on the line was then purchased which matched closely the control operation. As a consequence, equipment is working well within its capacity to produce and breakdown due to overstressing in an offort to balance out production is no problem.

But although the Packard facility is unique for a parsimony of equipment, the equipment used is the most modern available. You'll



A multitude of machining operations on V-8 engine cylinder blocks begins in this 11 station Ingersoll transfer machine, one of four in the 800 ft automated line in Packard's Utica plant, outside Detroit. Here inspected castings are loaded top side up and front end first for milling four locating pads with 4½ inch diameter carbide-tipped cutters. Blocks are then turned 180 degrees, by means of a turnover fixture to place the pan rail up for rough-boring half bearings for crankshafts and core-drilling for cam bearings, both operations being held within 0.005 inch total tolerance.



Five multi-station automatic machines are required to process cylinder heads in the V-8 engine line at Packard's plant in Utica, Mich. Here a 19 station transfer machine by W. F. & John Barnes drills cylinder bolt holes and push-rod holes; drills and countersinks valve cover holes; coredrills valve ports; spotfaces valve guide bosses; drills, countersinks and reams sparkplug holes and performs other operations.

find the latest from Micromatic and Greenlee, Gisholt automatic engine balancers fed by power and free conveyors and even a rotary engine test stand which completes the engine running test cycle in one revolution to deposit the engine back into the work flow.

Camshaft and crankshaft ways are bored in line and the bearings pressed in automatically. Sealant is applied to the block and welsh plugs inserted in the blocks automatically. After many machining operations, the blocks and heads are ejected automatically if they do not fall within tolerances as determined by the automatic gaging units.

Blocks are rotated by special fixtures between some operations to dump chips in cases where packing would cause tool breakage. And before entering the finish operations, they are washed thoroughly in a washer incorporated right into the line.

Although blocks progress without human assistance from one station to the next throughout the length of the line, over 200 inspections are performed on the block alone. In most cases the inspections are visual for machining finish quality and to insure that all operations have been performed. Provision is made for rejecting unsatisfactory blocks to the side by means of roller conveyor for repair or scrap.

In addition, the automation transfer units which transfer and position the blocks between each machine unit will automatically remove the block to a short roller conveyor storage unit if machine ahead is not ready to receive the cylinder block for any reason. Conversely, should the supply of blocks to the machine ahead be cut off for any reason, automation transfer unit will select blocks from the storage roller conveyor for delivery to the waiting machine ahead.

Other automation of interest in the plant includes a four-station Norton grinder setup which grinds the crankshaft bearings. Of the transfer type, the transfer mechanism consists of five heads which pick up the crankshaft and move it to the next operation including initial loading and final unloading. Each station grinds to size through tolerance limit devices controlling the wheel feed electrically. Wheels are automatically dressed as required and reduction in wheel size is automatically compensated for by the feeding mechanism.

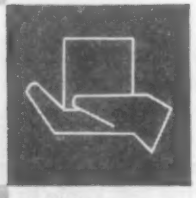
Call it parsimonious automation, nonduplicative automation or what you will: Packard figures it achieves operating costs comparable to other plants by avoiding multiple equipment and the multiple staffs to operate it.

the PRODUCTION ENGINEERING SHOW

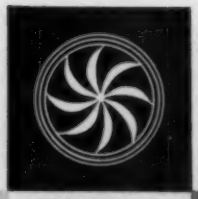
SEPTEMBER 6-16, 1955
NAVY PIER, CHICAGO

The Automation Exposition

MONITORING EQUIPMENT
such as: Recording and control equipment. Electronic devices. Switches, relays and electrical components. Counters and computers. Mass spectrometers.



HANDLING EQUIPMENT
such as: Conveyors, Cranes, Hoists, Monorails, Pneumatic tubes. Clamping, rotating and positioning equipment. Loading and unloading equipment.



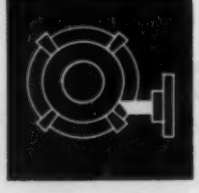
EQUIPMENT COMPONENTS
such as: Air and hydraulic mechanisms. Mechanical activators. Brakes, clutches and other drive mechanisms. Electrical, air and hydraulic motors.

GOVERNING EQUIPMENT
such as: Devices for tramp iron removal. X-ray, fluoroscope and photocell devices. Limit switches and governors.

COMMUNICATIONS EQUIPMENT
such as: 2-way radio. Telephone and paging systems. Teleprinters and facsimile. Industrial television. Special signaling equipment.

INSPECTION AND GAGING EQUIPMENT
such as: Air gages. Strain gages. Beta ray thickness gages. X-ray gages. Optical gaging equipment.

SPECIAL PRODUCTION EQUIPMENT
such as: Continuous heat treating and drying furnaces and ovens. Abrasive blasting and other finishing equipment. Engineered paint systems. Weighing and proportioning equipment.



MACHINE TOOL ACCESSORIES
such as: Bearings, Cutting tools, coolants. Chucks, dies, jigs. Lubrication systems. Portable tools. Power transmission equipment.

What's Your Problem?

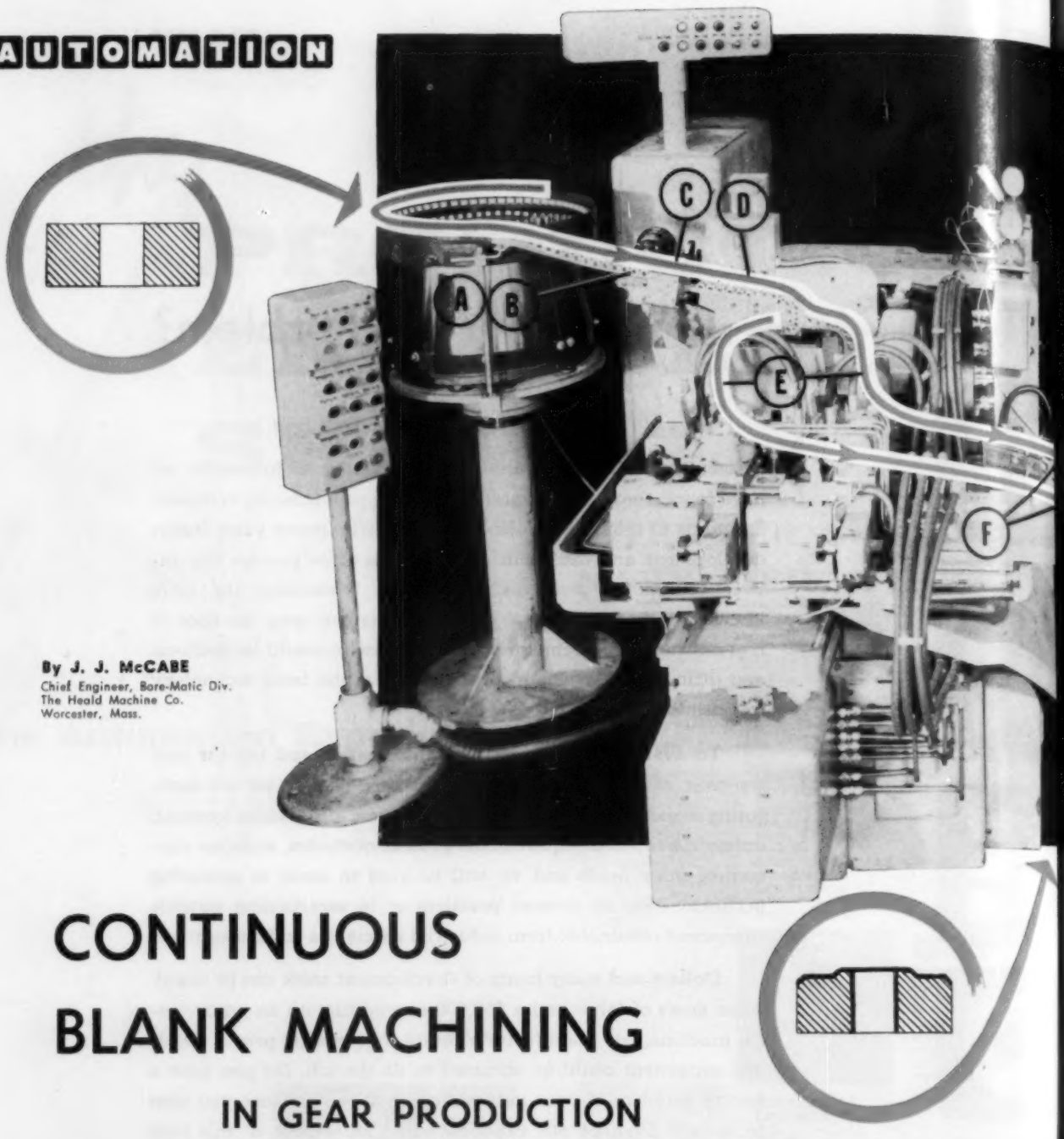
In our work with companies in a wide variety of industries, we have found that fundamental engineering problems are common. Solutions to difficult problems achieved after many years study, development and testing in one field can often provide the answer to similar problems in another. Sometimes the mere knowledge that a practical solution exists can open the door to real advance with techniques which otherwise would lie dormant and little used. Development of this horizontal basic technology is a primary aim of AUTOMATION.

To avail our readers of such information and tap the vast reservoir of practical know-how across industry, we are instituting a special service. If in planning new automation systems, unfamiliar or new requirements present obstacles, write us concerning your needs and we will be glad to assist in procuring pertinent data on present practices or in ascertaining suitable equipment obtainable from industrial specialists and consultants.

Dollars and many hours of development work can be saved. After years of labor and a $50,000 expenditure on an unsuccessful machine, one manufacturer found that modest priced standard equipment could be obtained to do the job. Do you have a knotty problem in your automatic operations or those you plan to install? Perhaps our experience and knowledge of this field can help establish contacts leading to practical solutions.

EDITOR

AUTOMATION



CONTINUOUS BLANK MACHINING

IN GEAR PRODUCTION

By J. J. McCABE
Chief Engineer, Bore-Matic Div.
The Heald Machine Co.
Worcester, Mass.

In an installation which at first glance could be thought to be very complex, more or less standard machine tools and accessories with fairly simple controls are automatically preparing gear blanks. Co-ordinated elements of this operation are performed by independent machining units

AUTOMATION has been aptly defined as "the science of manufacturing, processing or performing functions as automatically as possible within practical economic limits." In general, it seems that the trend toward industrial automation will probably be confined for the present to individual production lines for the purpose of performing all or most of a sequence of finishing operations to a given workpiece.

Though the term automation is relatively new, applications of various automatic features by machine tool builders have automated machine tools to varying degrees for almost 30 years. Auto-

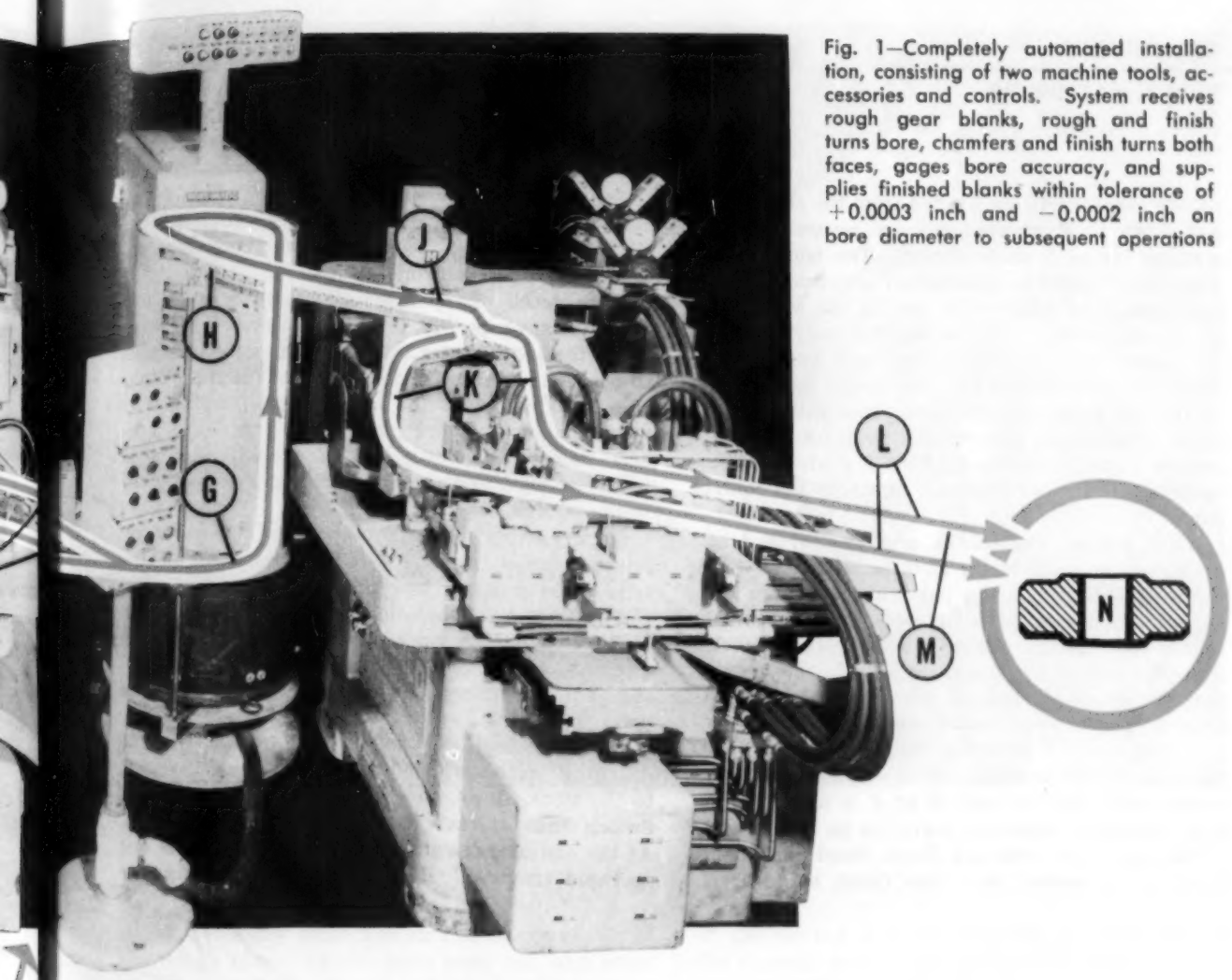


Fig. 1—Completely automated installation, consisting of two machine tools, accessories and controls. System receives rough gear blanks, rough and finish turns bore, chamfers and finish turns both faces, gages bore accuracy, and supplies finished blanks within tolerance of +0.0003 inch and −0.0002 inch on bore diameter to subsequent operations

matic size control and automatic gaging for precision grinders, automatic cycling and automatic loading for both grinders and precision boring machines represent a few of the many such devices. These long accepted features might be said to represent automation in its infant stage. Now in the period of adolescence, automation is represented by an integrated line of machines rather than a single automatic unit. The adult stage, yet to come, will probably be the automatic factory.

Characteristic of the new concept in its present stage are the automatic transfer machines used primarily by the automotive industry. Predicated upon the transfer machine's success, a large automotive manufacturer is now in the process of automating production of pinion gears.*

Raw stock is fed into a first machine and finished parts emerge from the end of the line. This article offers a quick look at the segment of this process where rough gear blanks are finish bored and faced.

Finish boring and facing of this gear line is being done by six Bore-Matics supplied by the Heald Machine Co. These machines are set up in three pairs. The first machine in each pair semifinish bores and generates one face of the piece. The second machine finish bores and generates the opposite face of the part.

Each pair of machines is set up as shown in *Fig.* 1. Gear blanks are fed by conveyor from previous operation into a Syntron feeder, *A*, which supplies a gravity feed system into the first machine. Bore of blanks is mechanically checked with *Go-NotGo* plug while momentarily held at *B*. If *NotGo* at *B*, the part is dropped out of line by trap door at *C*. The switch at *D* controls the feeder, *A*. As long as there are blanks in the chute at *D* the switch stays open; when there are no blanks at *D* the switch closes and the feeder operates for a predetermined interval before shutting off automatically. If the feeder immediately starts on a second cycle because no blanks have arrived at *D*, Machine I shuts off automatically and a red indicator lights on control panel.

Blanks are fed to twin chutes at *E* and two pieces per cycle are automatically loaded into chucks, semifinish bored, and finish faced and chamfered

*See—"Continuous Gear Production," AUTOMATION, April 1955.

on one side. Parts are ejected from the chucks and roll down to *F* where there are separate gaging stations for each work station. The bore of each piece is air gaged to determine the automatic compensation to be made on the boring bar with which it was machined. The boring bar may be automatically: (1) retracted if the bore gages above limit, (2) advanced if the bore gages below limit, or (3) left as is when the bore gages within limits. If the bores do not gage within limits for three successive machine cycles, Machine I shuts off automatically and a red indicator lights on the control panel.

After gaging, the blanks are released and roll by gravity chute to feeder at *G* for second machine. Entering this feeder the parts are laid over in a horizontal position with finished face up by a 90 degree twist in the chute. As the blanks emerge from the top of the feeder at *H* into the gravity feed system of Machine II, they pass through another 90 degree twist which returns them to a vertical position but presents the unfinished face to the tools on this machine. This second feeder runs continuously and the switch at *J* is used only to stop Machine II whenever there are no blanks at *J*.

Two parts per cycle are finish faced and chamfered on the second face then finish bored at *K*. After ejection into gravity chutes each blank is individually gaged at *L* and the boring bars automatically adjusted just as in Machine I. As in Machine I, Machine II shuts off automatically and a red indicator lights on the control panel if three consecutive parts gage outside limits. In addition, gages at *L* regulate trap doors at *M* which eliminate and segregate parts with bores which are undersize or oversize. Parts at *N* are ready for conveying to subsequent operations.

More detail of the machining area of each machine is shown by *Fig.* 2. Parts can be seen feeding down the twin chutes. The loading arm is shown in position at the bottom of each feed chute. When the chuck is ready for loading, the loading arm moves out, pulling one piece from each chute. This arm then moves down and in, placing the parts in the chucks, and the empty loading arm returns to the feed chutes.

Metal cutting on each machine is done by tools on two cam-actuated tool slides mounted on the cross slide pad and two boring bars bridged over the cross slide. Operations are carried on simultaneously for both work stations on each machine. For each work station one tool slide performs facing and chamfering operations and one boring bar performs boring and chamfering work. Machining uses a more or less standard cycle. On first or roughing machines, the tool table rapid traverses to the stock, slows, and bores in to a positive stop. Switch then starts cross slide to generate face. At the end of cross slide stroke, the table runs out at rapid traverse. Retraction of the boring bar

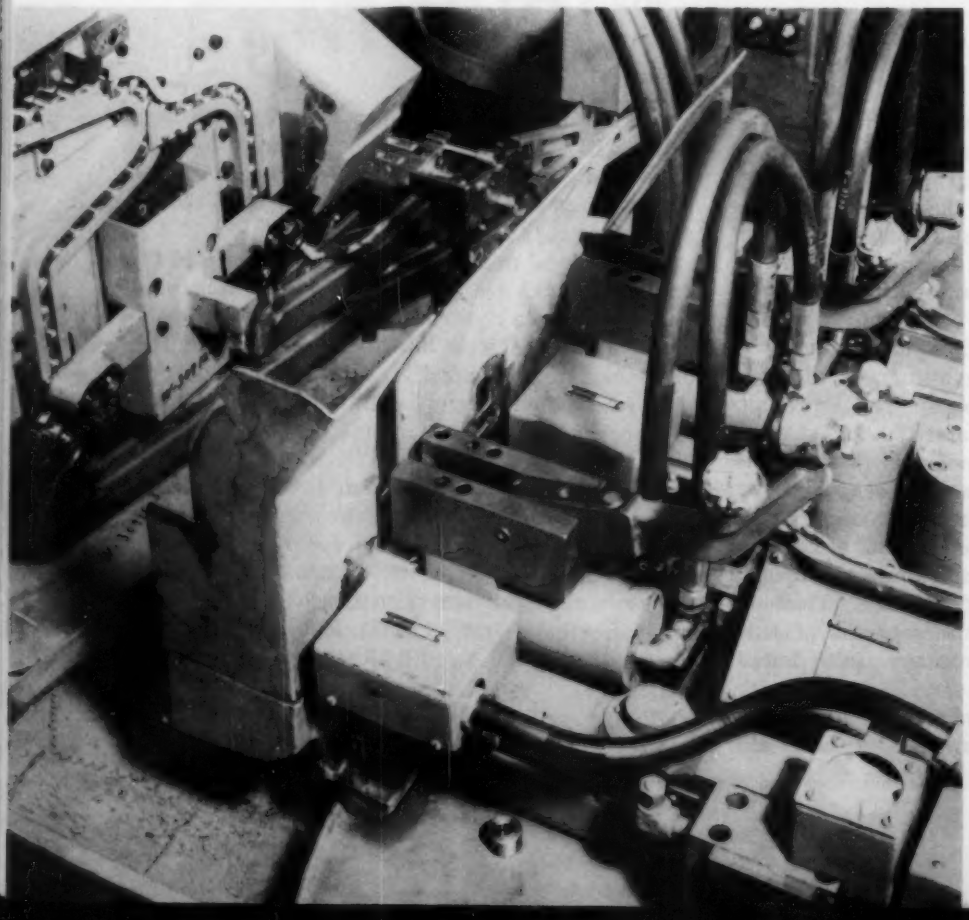


Fig. 2—Working area of machine tool unit for continuous boring, facing, and chamfering of steel gear blanks. Roughing units remove 0.014 inch of stock on bore diameter and finishing units remove 0.007 inch

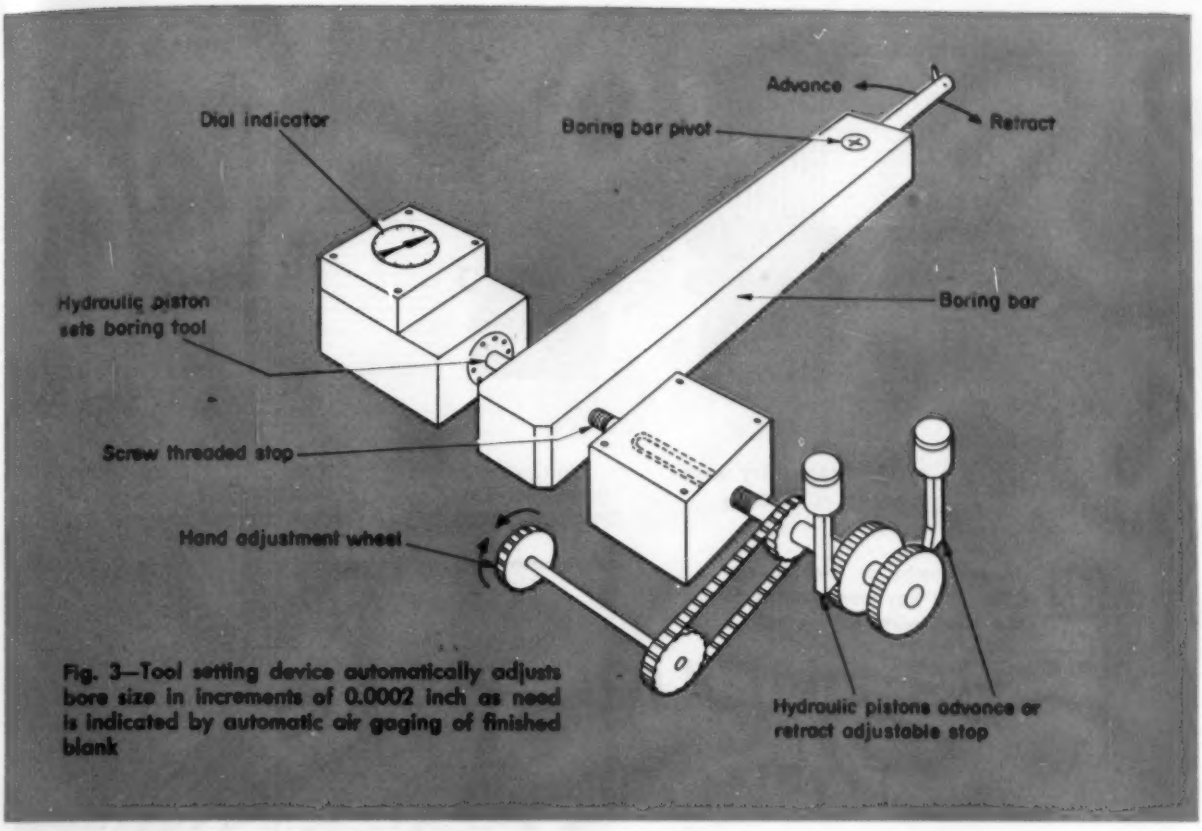


Fig. 3—Tool setting device automatically adjusts bore size in increments of 0.0002 inch as need is indicated by automatic air gaging of finished blank

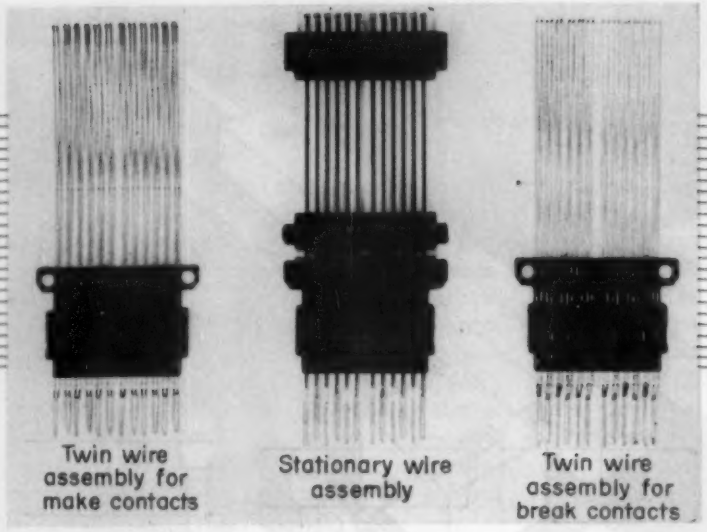
is not necessary since a drag line is acceptable in the rough bore. As the table runs out, any chips wound around the boring bar are removed by its hydraulically operated stripper. When the table reaches rest position, the chip strippers retract and cross slide resets to rear for the next cut.

The finishing or second machine is set up to rapid traverse in to a positive stop with boring bar in retracted position. At this point the second face of the piece is generated by advance of the cross slide to a second positive stop, then the boring bar is set to boring position and chamfers and bores as the table moves out. Boring out eliminates drag line in the finished bore. As on the roughing machine, the boring bar is stripped of chips, and boring bar and cross slide are reset for the next cut. Unloading chutes move up to receive parts ejected from the chucks, and the pieces roll to the gaging points. Then the unloading chutes drop down to rest position. Units gaging the finished bore actuate trap doors which drop out those pieces which gage outside limits and segregate oversize bores from undersize bores.

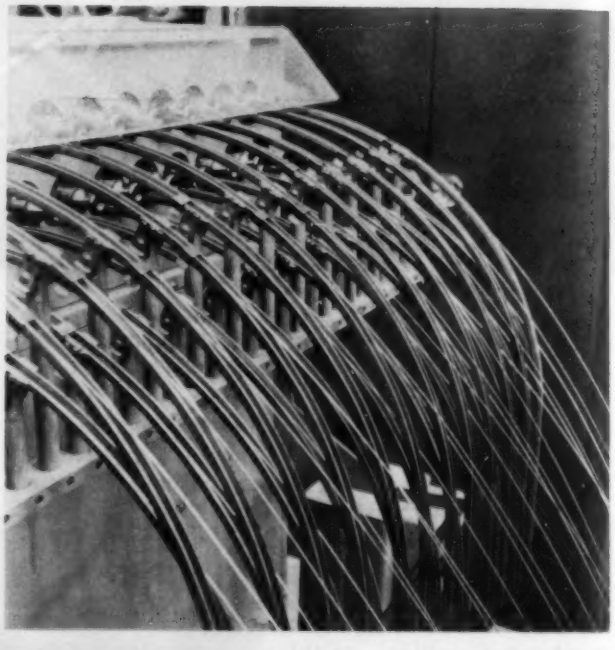
A unique feature of this installation is a tool positioning device, *Fig.* 3, which automatically adjusts boring tool settings to compensate for bore deviations registered by the gaging units. Each boring bar is adjusted independently as indicated by its individual gaging unit. The device consists basically of a horizontal boring bar which is supported and pivoted on a vertical axis. Position of the cutting is thus regulated by movement of the opposite end of the bar, which swings the boring bar about the axis.

Movement of the control end of the bar is limited by a screw threaded stop which bears against one side of the bar. A hydraulic piston bearing against the opposite side of the bar brings the bar against the threaded stop. In operation, the stop is adjusted by one of two ratchets attached to the screw. A hydraulic piston positioned over each ratchet turns the screw either clockwise or counterclockwise depending upon which piston is actuated by the gaging unit. When the air gaging mechanism at the output end of the machine indicates that the bore is undersize, a valve is energized which causes the proper cylinder to operate its ratchet and back off the screw. This allows swinging of the boring bar to bore the next hole larger. Gage indication of an oversize bore results in a similar train of actions which sets the boring bar to bore a smaller hole. For resetting or replacing boring tools a knob is provided for manually adjusting the screw, and a dial indicator aids the setup man in making adjustments.

Though some details of this installation are quite unique, the overall design is practical and straightforward and illustrates the application of automation without highly complex specialized machines and controls. This type of automation is of practical value to small shops as well as to industrial giants.

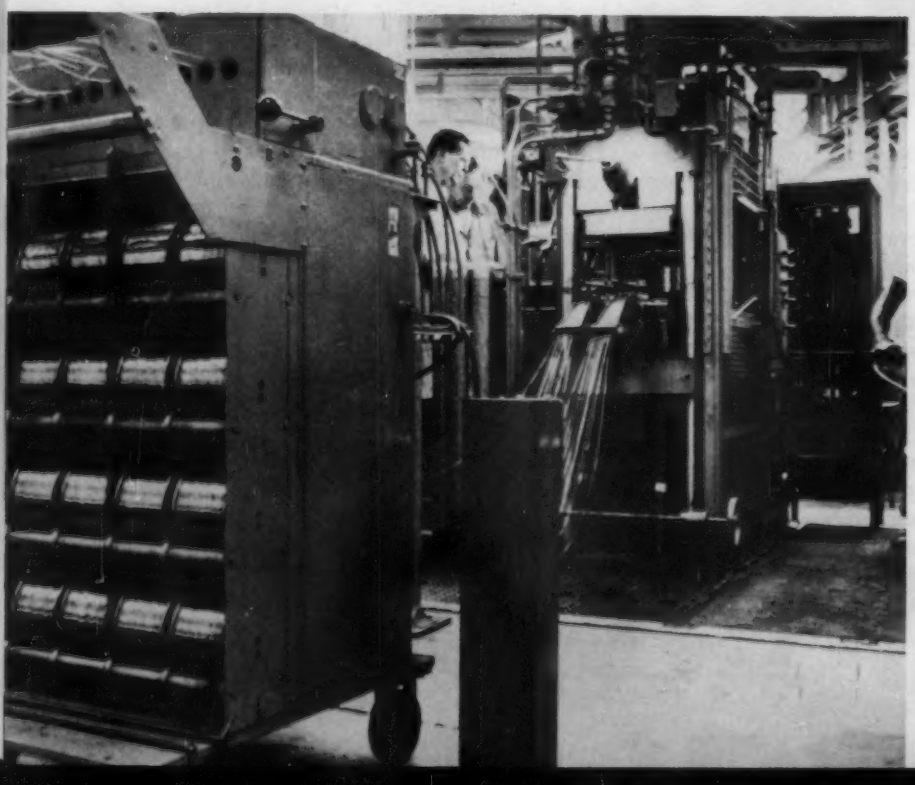


1 These combs or wire assemblies are key components in the new wire spring relays



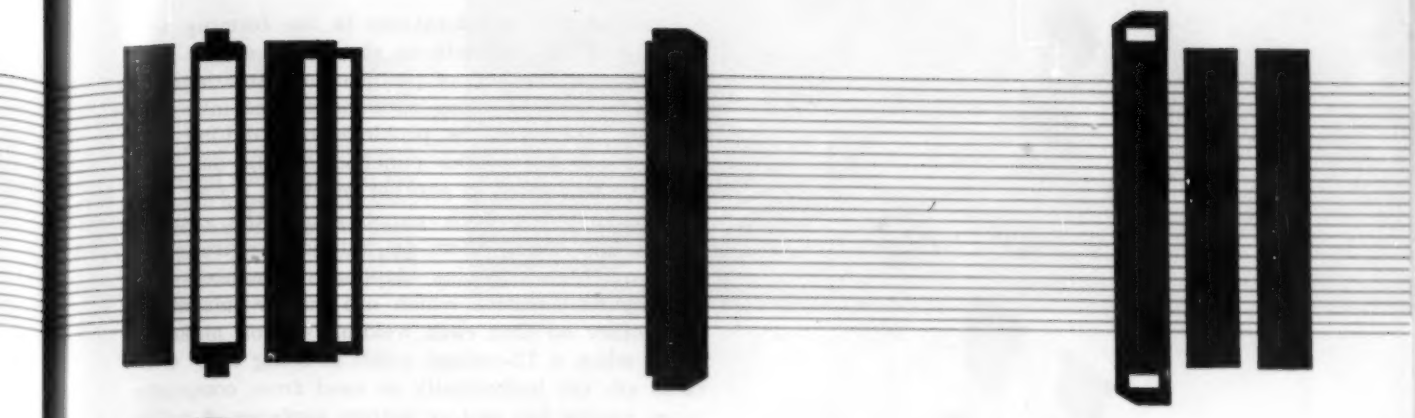
2

Wires for combs may be uncoiled from spools, straightened, and fed 24 at a time out these chutes to plastic molding presses. The wires are straightened by passing between two rotating dies



3

Straightened wires are fed directly to automatic plastic molding presses where phenolic plastic blocks are molded around the wires and serve to accurately position as well as insulate them



AUTOMATION TODAY

PRODUCING RELAY COMPONENTS

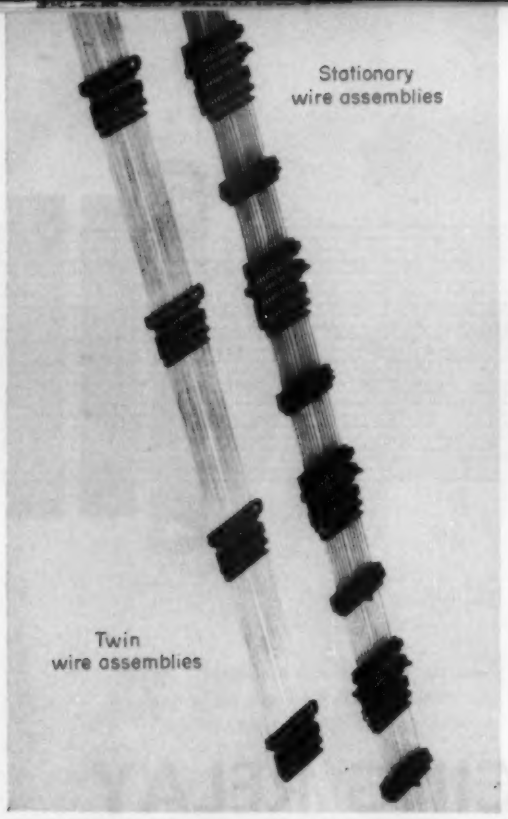
IN PRODUCTION at their Hawthorne Works is an installation that is one of Western Electric's most automatic manufacturing systems. They have long employed automatic methods in manufacturing component parts, but this system represents one of their advanced applications of automation to a series of operations.

This system has been under development for more than six years to manufacture the key components for the wire spring relay—the new relay which was designed with automatic production in mind (See—AUTOMATION, Sept. 1954). A big undertaking, this new manufacturing system called for revamping more than an acre of floor space, and the development and acquisition of new machinery and tools to perform the operations required.

The parts produced in the automated installation discussed here consist of an array of wires and contacts accurately fixed in molded phenolic plastic blocks. These wire assemblies are the contacting elements of the relay, and are called *combs*. Each relay may require three different combs: a twin wire assembly for normally open contacts, a stationary wire assembly, and a twin wire assembly for normally closed contacts. The stationary wire assembly consists of 12 wires fixed in plastic blocks with a contact welded on one end of each wire if desired, and the opposite end formed into a terminal and tinned. Each twin wire assembly incorporates 24 wires fixed in a plastic block. Usually each wire has an independent contact welded to it with the terminals on these assemblies being formed from a pair of adjacent wire ends. This construction provides two independent wires to make and break each contact with a stationary wire, so that open contact troubles should be greatly reduced. Variations in these components may be made to produce different units which are required—such as omission of contact on certain wires, etc.

To produce the combs from wire, plastic stock and tapes of contact stock, operations are performed in two general types of automated lines, there being several lines of both types in this installation. The first type of operations group straightens the wires as they are taken from spools, molds the plastic blocks around them, and cuts the wires to form unfinished combs. In the second type of operations group the rough combs are trimmed, contacts are punched from tape stock and welded to wire ends, the contacts are sized, terminal ends are brushed, the terminals are formed, the wires are bent to shape, and the terminals are cleaned and tinned.

Hundreds of development problems faced the engineers and machine builders before production could begin rolling. Among them were such posers as how to straighten miles of coiled wires as they came off spools—24 wires at a time—and keep them that way. Then the wires must be accurately



4 Molded plastic and wire assemblies before they are cut into separate units

fixed in the molded plastic supporting and insulating blocks.

Some of the considerations in the forming and welding of the contacts on stationary combs give a glimpse of the type of problems and solutions involved in putting these automated lines into production. To avoid the problems of handling and feeding contact blocks punched out in one machine to be welded in another machine, a unit was developed which both punches out the contact blocks and welds them to individual wire ends. This machine contains duplicate punching and welding mechanisms which are mirror images of each other so that each welding station makes 6 welds when a 12-contact comb is being run. Contacts are cut individually as used from composite tapes having top and/or bottom surfaces of palladium, and may be cut from any one of three different tapes. Variation of contacts is required by varying relay applications so that each wire may have: (1) no contact, (2) contact with palladium cap up, (3) palladium cap down, or (4) palladium cap both up and down. The three tapes for each head feed from opposite sides and enter the shearing dies through individual openings. However, only one tape per cycle is advanced into the die

5 After being cut into units, twin wire combs are loaded into an automatic magazine feeder such as that at far left and progress automatically through the operations necessary to finish these components. Operators at discharge magazines unload completed combs which have been stacked in carriers for transfer to assembly operations. Maintenance man in center is inspecting the automatic resistance welding unit such as used for twin wire assemblies

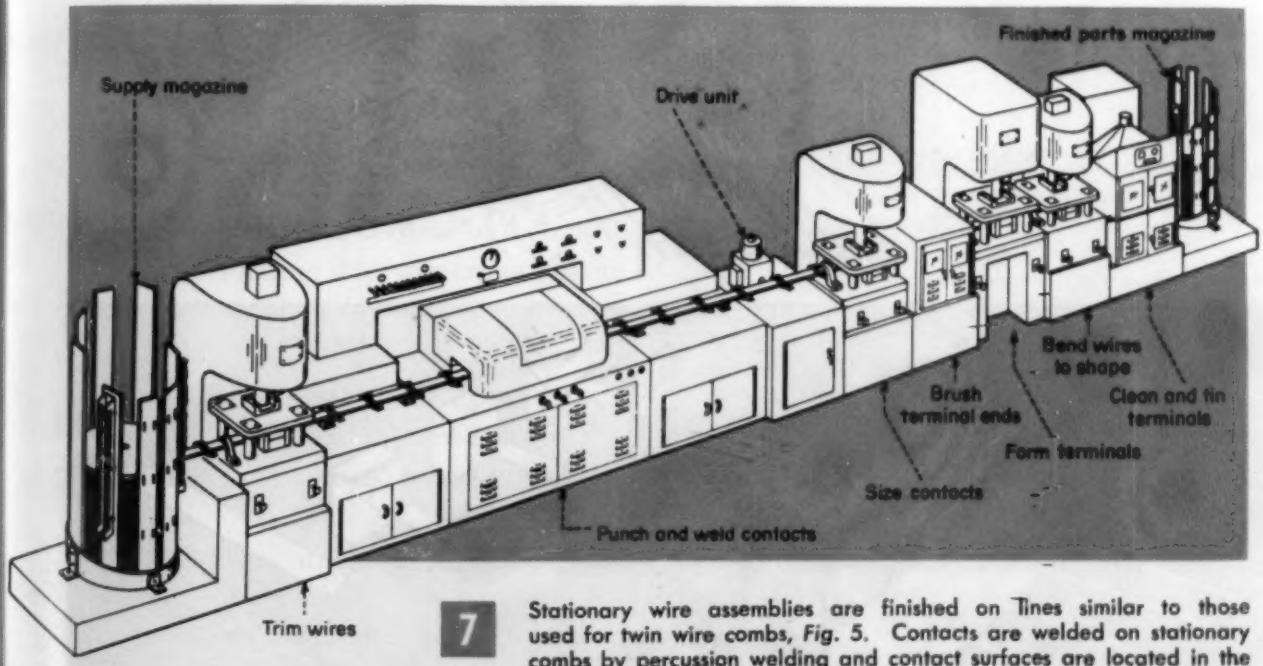
6

Operations from rough comb to finished component on the automatic lines are controlled from panels such as this. Each operation on the associated line can be started or stopped from this location

by the selective hitch feeder and subsequently sheared. Adjustable knobs on both right and left tape feed cams are set to give one of the four tape feed conditions for each wire position of the comb. The punch delivers the sheared contact to a transfer finger at the end of the shearing stroke, and the transfer finger removes the contact from the punch notch, slides it through a guide channel and into the welding jaw.

Contacts are welded on twin wire assemblies by resistance welding but the method of percussion welding was chosen to weld contacts on the stationary wire assemblies. This method consists essentially of charging a capacitor to a high potential and discharging it across the gap between parts as they approach each other under a propelling force. The abutting surfaces are heated by the arc before they collide so that as they come together percussively the weld is made. This method of welding was selected mainly for the following reasons:

1. Accuracy of location can be obtained since electrodes may be placed well away from the weld zone. This means the electrode clamping force may be prevented from deflecting the wire ends and causing misalignment of contacts.
2. The lesser current required for arc welding as compared to resistance welding makes it possible to conduct this current through the wires from the opposite end without heating them appreciably, and metals of high heat conductivity and high electrical conductivity can be joined.
3. A suitable heat balance can be readily obtained in the weld zone even with unequal size and differing electrical and heat conductivities of abut-



7

Stationary wire assemblies are finished on lines similar to those used for twin wire combs, *Fig.* 5. Contacts are welded on stationary combs by percussion welding and contact surfaces are located in the same plane across the 12 wire positions within a tolerance of ±0.002 inch

ting parts. This would be difficult by slower heating methods which heat larger areas.

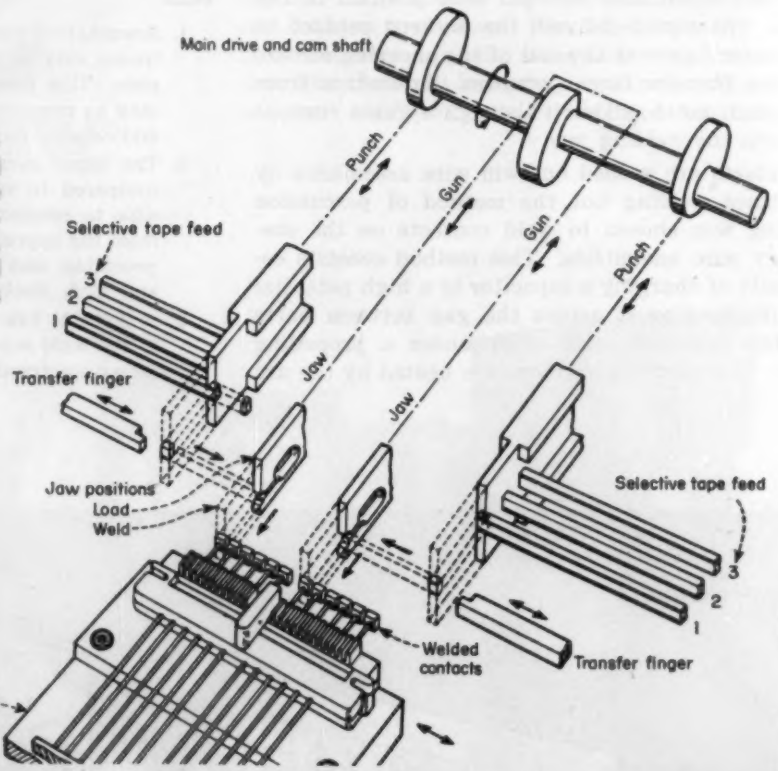
4. The fast welding time makes this method especially useful in high speed automatic welding machines.

The contact block, held in the jaws of the welding gun, is propelled toward the wire end by a spring upon release by a cam. There is an interval between the release points of the two welding guns in a machine to avoid electrical or mechanical interference. To prevent burning of welding jaws due to undersize contact blocks or out of position wire ends, switches sense these conditions and trigger thyratrons to discharge the capacitors approximately ¼ second before the weld would take place. Signal lamps indicate at which switch the trouble is occurring.

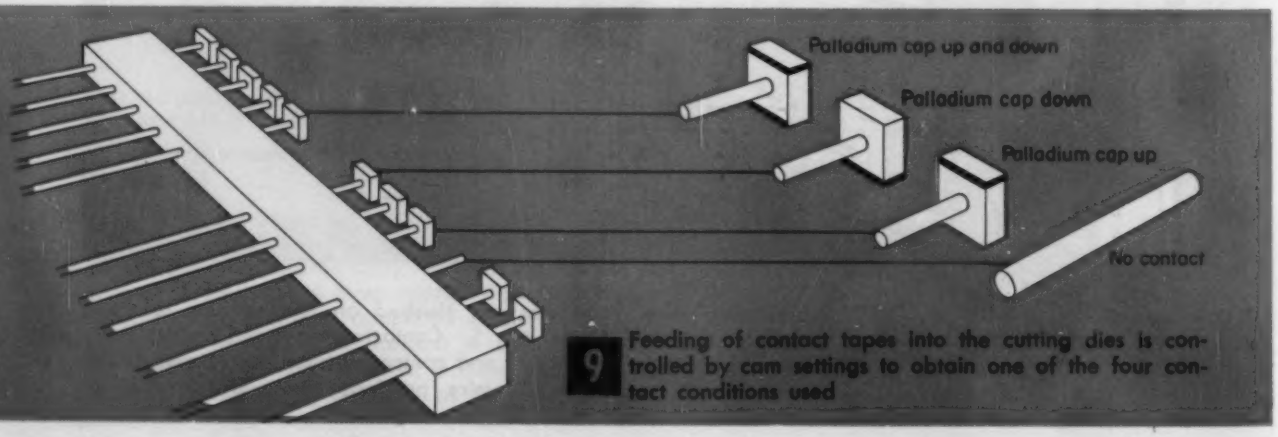
After the weld is made, the jaws are pulled away from the contact and the gun positioned for the next cycle. In retracted position the jaws are cleared by an ejector blade of any contact which might stick in the jaws because of weld failure.

Safety from the high voltage present is provided for personnel by door switches, solenoid released shorting bars and bleeder resistors on the capacitors. Provision for mechanical jams was made with a slip clutch on the main drive gear and a pull out clutch and automatic stop switch in the drive of the workpiece transfer mechanism.

Although thousands of relays are now being turned out annually, peak production will not be reached until 1956, when this plant will be able to turn out 3½ million a year. This sizeable jump in output for these components is only one of the myriad production increases which are constantly necessary to keep pace with expanding demands.



8 For stationary wire assemblies, contacts are cut from selectively fed tape stocks and welded to wire ends in a single unit having duplicate cutting and welding heads. Six cycles of both heads are needed to cut out and weld twelve contacts on a stationary comb



9 Feeding of contact tapes into the cutting dies is controlled by cam settings to obtain one of the four contact conditions used

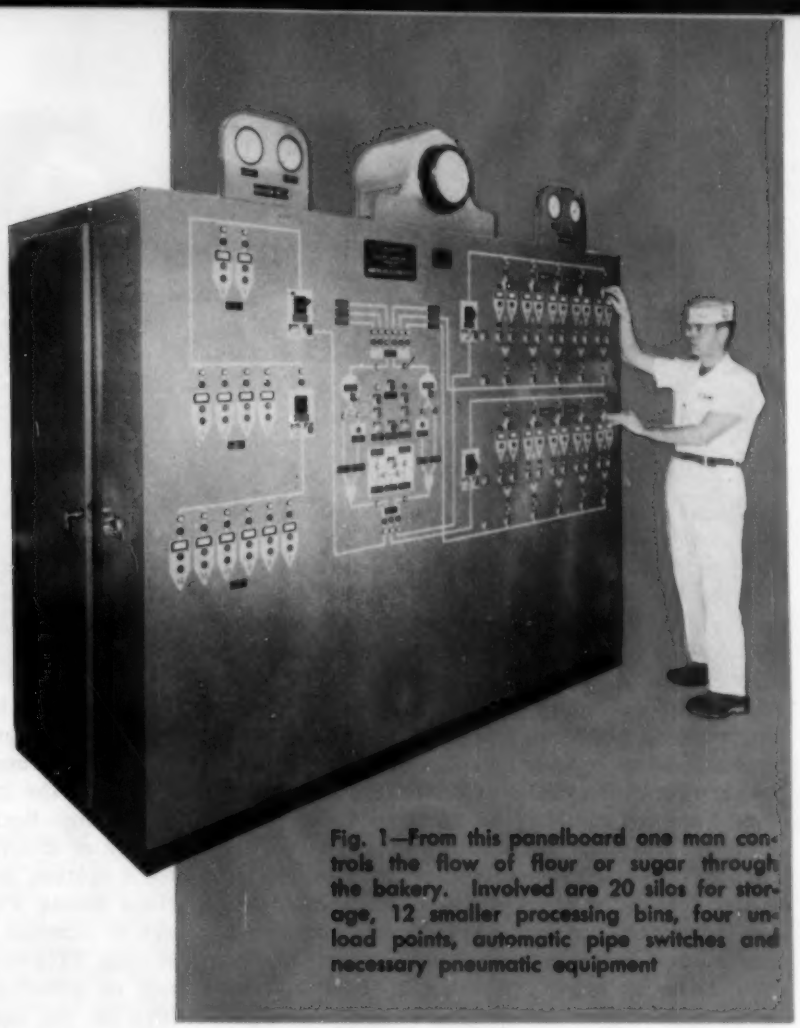


Fig. 1—From this panelboard one man controls the flow of flour or sugar through the bakery. Involved are 20 silos for storage, 12 smaller processing bins, four unload points, automatic pipe switches and necessary pneumatic equipment

MOVE IT WITH AIR

Remote control of a complex interlocking duct system is possible in modern pneumatic conveying. The resulting flexibility and obvious advantages of moving dry pulverized material through a closed pipe line combine to create a model automated system

PNEUMATIC CONVEYING of dry bulk materials is one of the older forms of automatic handling. Considering the relative ease of meeting the particular capacity requirements in any given plant and that the advantages extend from increased safety to simple convenience of installation, pneumatic conveying offers a possible solution to the problem of bulk handling of dry materials in all size plants and industries.

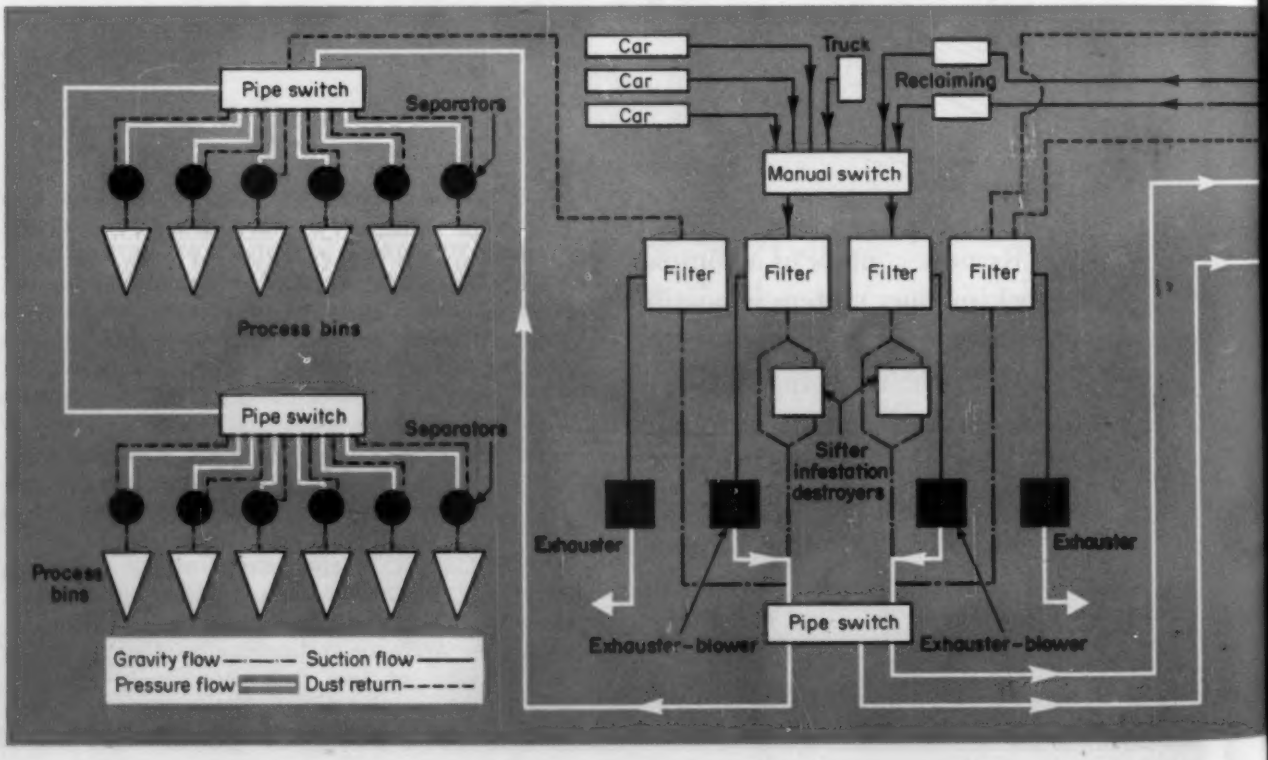
Modern installations reflect the advanced engineering techniques which exploit the practical attributes of moving certain materials by means of air. Receiving, storing and in-plant movement of flour and sugar at the bakery of the American Stores Co. of Philadelphia furnish an excellent example of a modern pneumatic system. Briefly stated, the Airveyor system, designed by the Fuller Co., consists of two positive-pressure type exhauster-blowers interconnected with air locks, filters, separators and bins through closed duct

Fig. 2—Bulk shipments of flour or sugar are unloaded through a simple connection of a flexible suction line to special hopper outlets on transports. Bagged material is emptied into a special hopper at the receiving point

work and automatic pipe switches, controlled from a master control board, *Fig.* 1.

Flour and sugar are normally received in bulk form by special trucks and railway cars provided with hopper outlets. Design of the outlet is such that flexible intake hoses connected to the vacuum side of the pneumatic system can be attached quickly for unloading operations, *Fig.* 2. From the receiving platform, material is conveyed to a receiving filter capable of separating solids and 100 per cent of the visible dust from the air stream. Should bagged material be received rather than bulk lots, the bags are emptied immediately into a special bag-dump hopper which can be connected to the flexible intake hose used to unload bulk cars. A rotary air lock provides for continuous, fully automatic discharge from the filter hopper. Flour flows by gravity through a sifter and infestation destroyer and into a second automatic air lock for discharge into the blower line of the system. Sugar, by-passing the sifter and infestation destroyer, flows directly into the air lock. This equipment forms the nucleus of a pneumatic conveying "pull-push" type of system. The air supply machine, *Fig.* 3, creates a vacuum to "pull" material from one point to an air-material separating unit; material discharges through a rotary air lock into the blower side of the air supply machine which provides "push" for further movement of the material to some desired point.

One of the important advantages of pneumatic conveying—flexibility—is provided by the multiplicity of discharge points which can be designed for a system, and the ease of directing material to these points, *Fig.* 4. In the bakery, incoming flow can be directed to one of 20 silos, each capable of storing 62½-tons of material, *Fig.* 5, or the flow can be directed to one of 12 smaller processing bins on the bakery floor in another part of the building. Choice of direction is controlled from a



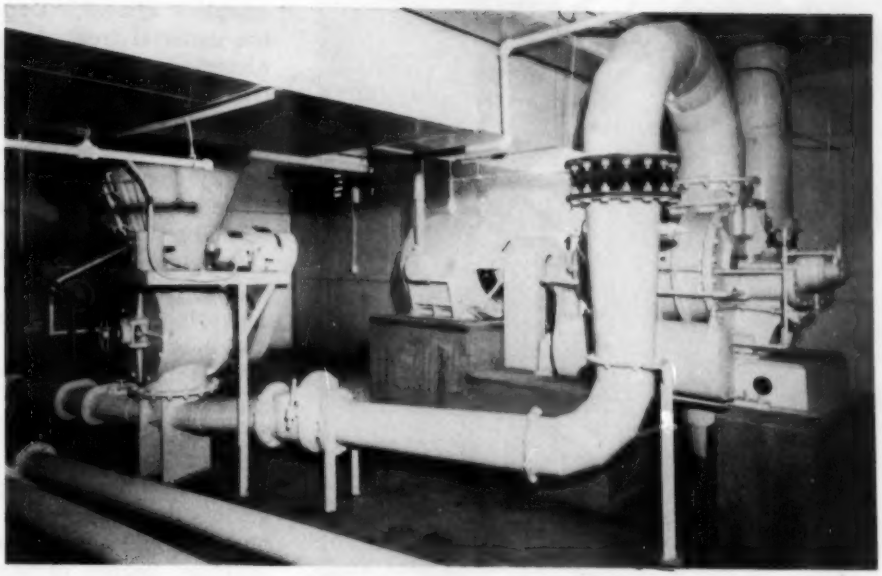


Fig. 3—One of two exhauster-blowers which supplies vacuum for conveying material to filters and pressure for blowing material to receiving bins. To the left is a rotary air lock which delivers flour or sugar from filters to blower side of system

master control board containing indicating lights, pushbuttons and selector switches positioned on a schematic diagram of the duct layout. Silos are provided with high level indicators and processing bins with both high and low level indicators which are connected to the indicating lights on the control board to guide the operator. Remote control pipe switches direct the flow path through the various combinations of transporting lines.

Material is removed from the air stream at the silos by cyclonic separators located above the silos. Each separator serves two silos, *Fig.* 6. Exhaust air from the separators is directed back to a secondary filter near the main blower system for complete separation of dust from the air stream before the air is discharged to the atmosphere.

The equipment which delivers flour and sugar from transport to plant can be considered as one

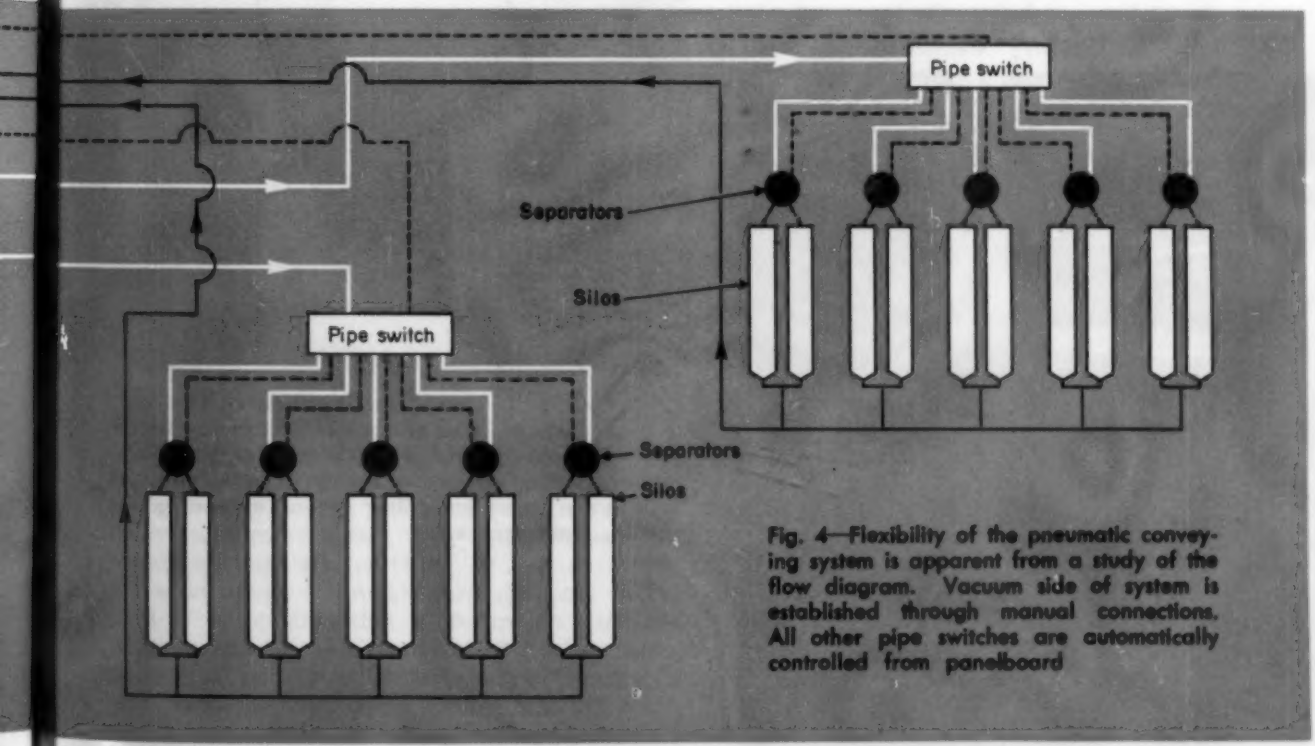


Fig. 4—Flexibility of the pneumatic conveying system is apparent from a study of the flow diagram. Vacuum side of system is established through manual connections. All other pipe switches are automatically controlled from panelboard

Fig. 5—Each of the 20 storage silos can hold 62½ tons of material. Material is conveyed to these silos through vertical pipes at right

Fig. 6—Motor driven, remote controlled pipe switch in center diverts material to individual cyclonic separators serving storage silos. Each separator serves two silos; switching is controlled at remote panelboard

complete system. Duplicate equipment, to move the material from storage to the processing floor, comprises a second system. Vacuum lines feed from the silos through a primary filter into an air lock for discharge into blower lines for delivery to one of the processing bins, *Fig.* 7, located on the bakery floor. Air is exhausted through another secondary filter for complete dust removal before discharge to atmosphere.

In addition to the obvious flexibility of operations, an appreciation of the value of pneumatic conveying to this bakery is contained in the statistics of the capacity of the system; unloading from freight car to storage may be done with both systems simultaneously to obtain a total flow of 40 tons per hour; either system can reclaim flour or sugar from storage for delivery to processing at the rate of 20 tons per hour. The closed conveying lines provide a dust-free working atmosphere, minimize explosion hazards and provide an exacting degree of sanitation required for food handling devices.

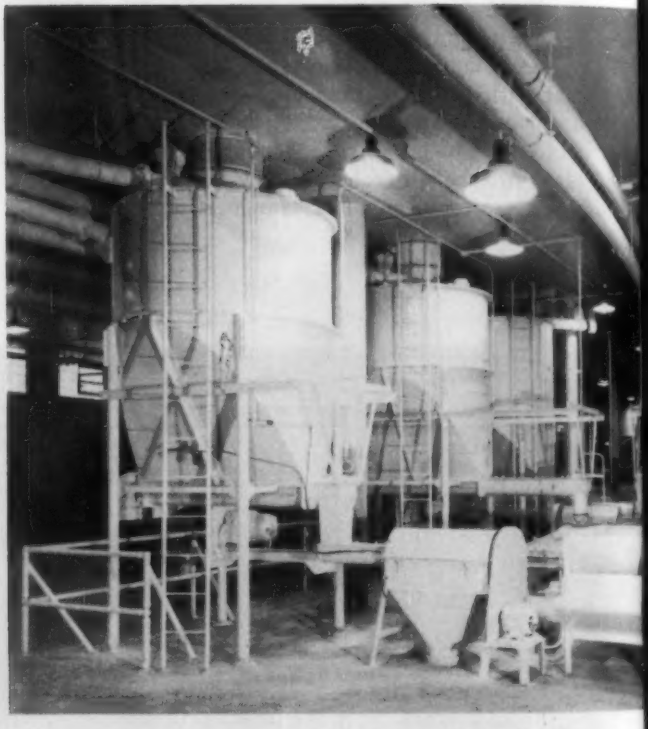
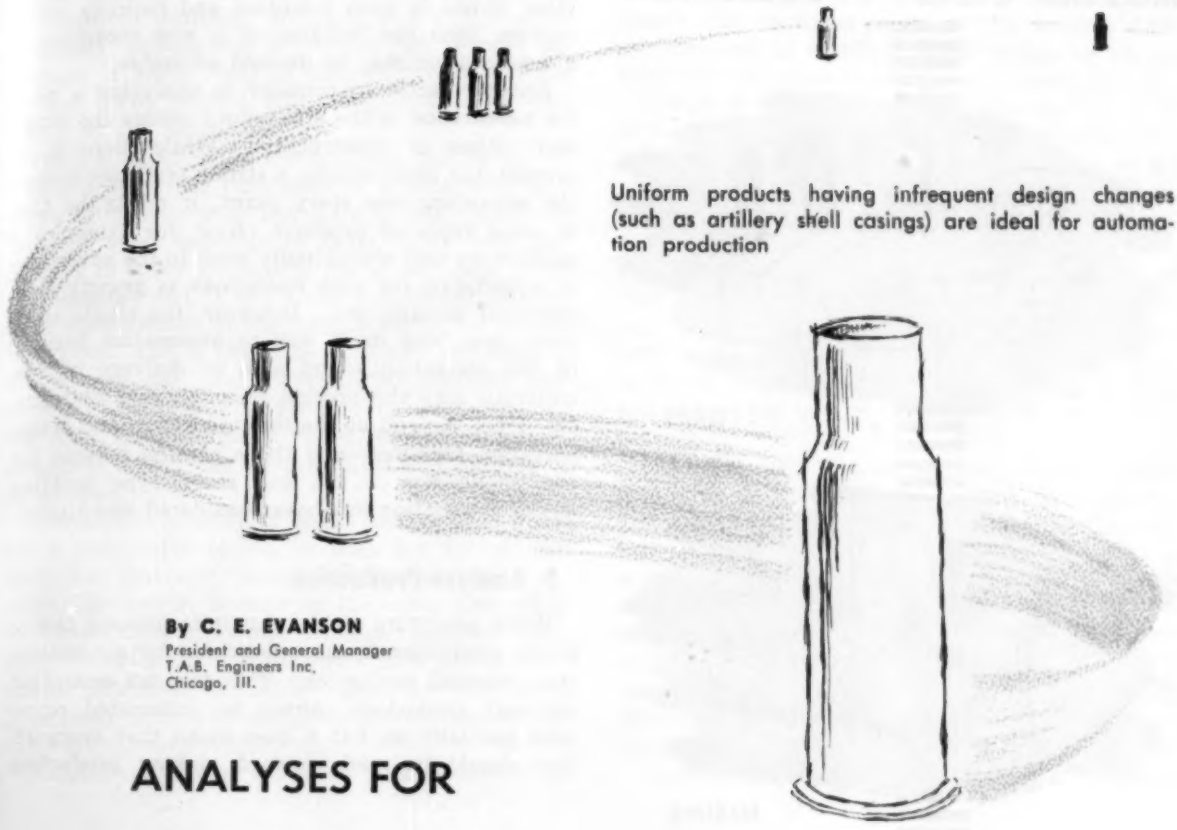


Fig. 7—Twelve small processing bins are ultimate goal of material. Blower air which delivers flour or sugar to these bins, from either transport or storage, is passed through a secondary filter before exhausting to atmosphere



Uniform products having infrequent design changes (such as artillery shell casings) are ideal for automation production

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ANALYSES FOR

AUTOMATION PLANNING

No one should go off halfcocked into automation! Industrial management having recognized the need for a thorough study before launching an automation program must decide what points to analyze and what considerations to appraise in this evaluation

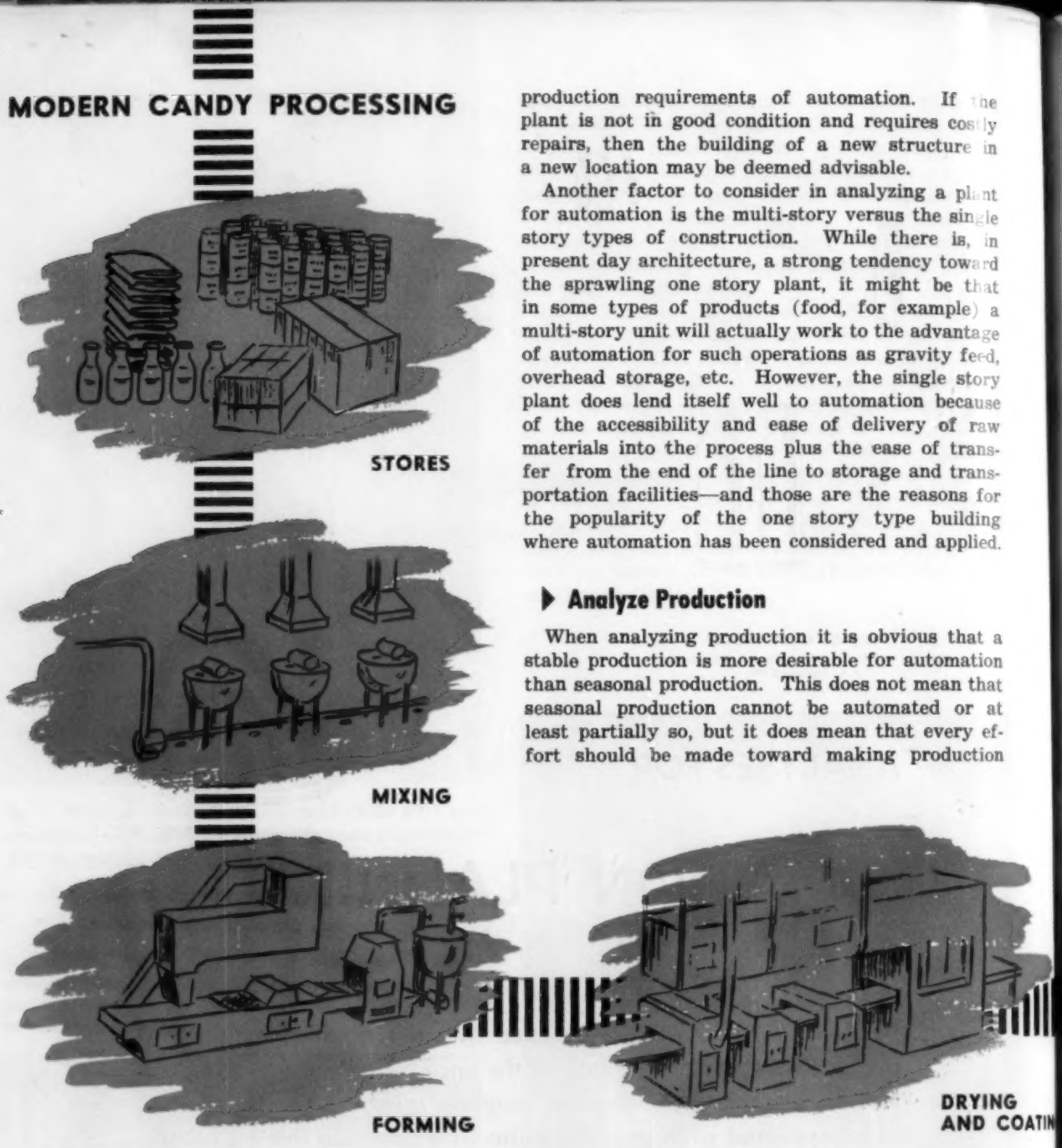
HOW CAN I determine if my company is ready to take advantage of automation? How can I determine if automation is practical for my plant? What are some of the conditions I must look for and expect to find?

These are the questions most frequently asked by progressive executives who recognize that automation with all of its promising potentials is here today—and growing fast. They are good questions —they are highly important.

We have found through our experience in the field of automation that there are no hard and fast answers to these questions. Yet, there are a number of factors which will indicate in general what should be considered and investigated before an attempt is made to set up an automation program. While we cannot, of course, cover every type of industry or condition, nevertheless, we can point out the more important subjects to analyze and what to look for. When applied to a specific instance the type of appraisal or analysis discussed in the following paragraphs will aid top management in answering the typical questions mentioned above.

Analyze Plant and Building

Some think that automation means tearing down existing facilities and erecting new ones, but that is not entirely true. In fact, the present plant, though old, may very well be used for automation and particularly for partial automation. Actually



in converting to partial automation, a new plant would probably not be justified.

What is important is the necessity that the old building be in good condition so that it will last for many years to come. In other words, a company would not want to spend a substantial sum of money renovating a plant that management thought it would want, or need, to move away from or replace in a few years. Furthermore, the plant must be adequate for the job to be done which means that it should be suitable for straight line production and should permit the volume of production that is anticipated in the next decade and beyond.

The age and condition of the plant and building, of course, are important for other reasons. If it is too old, its facilities may be insufficient for the greater power, water, sewage disposal and other production requirements of automation. If the plant is not in good condition and requires costly repairs, then the building of a new structure in a new location may be deemed advisable.

Another factor to consider in analyzing a plant for automation is the multi-story versus the single story types of construction. While there is, in present day architecture, a strong tendency toward the sprawling one story plant, it might be that in some types of products (food, for example) a multi-story unit will actually work to the advantage of automation for such operations as gravity feed, overhead storage, etc. However, the single story plant does lend itself well to automation because of the accessibility and ease of delivery of raw materials into the process plus the ease of transfer from the end of the line to storage and transportation facilities—and those are the reasons for the popularity of the one story type building where automation has been considered and applied.

▶ Analyze Production

When analyzing production it is obvious that a stable production is more desirable for automation than seasonal production. This does not mean that seasonal production cannot be automated or at least partially so, but it does mean that every effort should be made toward making production more stable and uniform throughout the year. This has been done many times by finding another item to manufacture during the principal product's slack season.

Next, the product should be one whose basic design remains fairly constant (with only minor changes) for a period of three of more years—such as occurs in the Automotive industry. Sometimes a product can be redesigned for automation or converted into a uniform state suitable for automation processing. In the latter case for instance, nonuniform food items have been converted successfully to another form and thereby made suitable for automation. An example of this is the automatic processing of juices and liquids from nonuniform solids.

If a change in the product is necessary to make it suitable for automation, such a change or new

design must be based upon a market analysis for assurance of customer acceptance of the product. Obviously, redesigning a product just to take advantage of lower costs of manufacture would not be wise. The product still must be saleable—and usable by the purchaser.

Today's buyer looks for uniform quality in the products he or she purchases. If a housewife buys a can of tomato juice and likes it, she expects to find the same qualities of taste, color, and consistency in every succeeding can of the same brand she obtains—and if she finds a different quality, she's disappointed. If the juice is worse, her reason is obvious. And if the juice is better, she feels as though she has been "gyped" on previous purchases. That is why we stress over and over again the need for uniformity based on pre-established standards which can be controlled and assured in automation.

Although constancy of basic design is desirable for a reasonable period, it does not follow that short run products cannot be processed by automation. However, because of the costs involved in an automation program, a close analysis of a specific case will probably reveal that partial automation principles should be considered particularly in those phases of the production process where costs are relatively high.

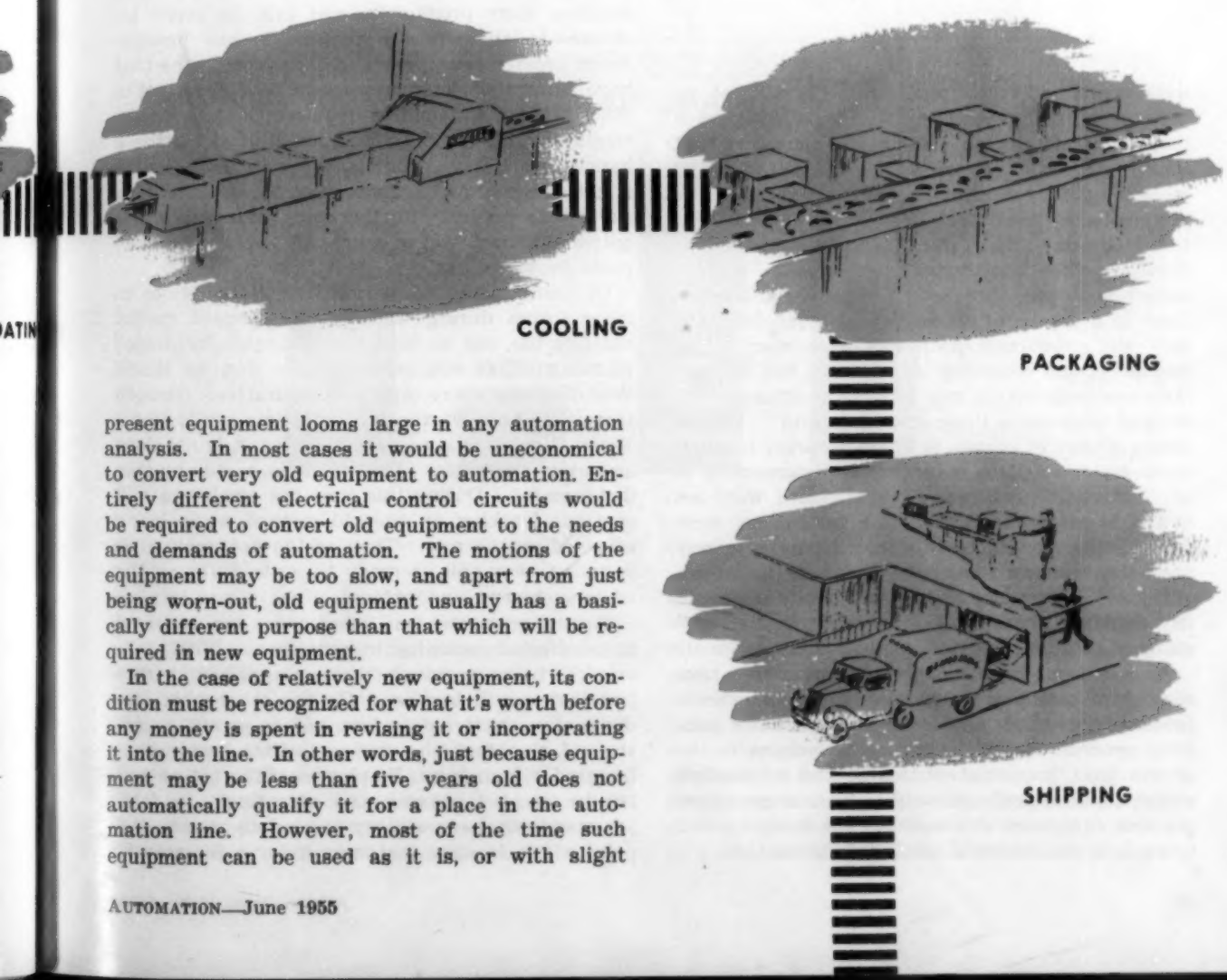
Naturally, the age, condition, and design of the present equipment looms large in any automation analysis. In most cases it would be uneconomical to convert very old equipment to automation. Entirely different electrical control circuits would be required to convert old equipment to the needs and demands of automation. The motions of the equipment may be too slow, and apart from just being worn-out, old equipment usually has a basically different purpose than that which will be required in new equipment.

In the case of relatively new equipment, its condition must be recognized for what it's worth before any money is spent in revising it or incorporating it into the line. In other words, just because equipment may be less than five years old does not automatically qualify it for a place in the automation line. However, most of the time such equipment can be used as it is, or with slight modifications. Often nothing more than a transfer means must be added to convey the material from one machine to another—which brings us to the subject of materials handling and automation.

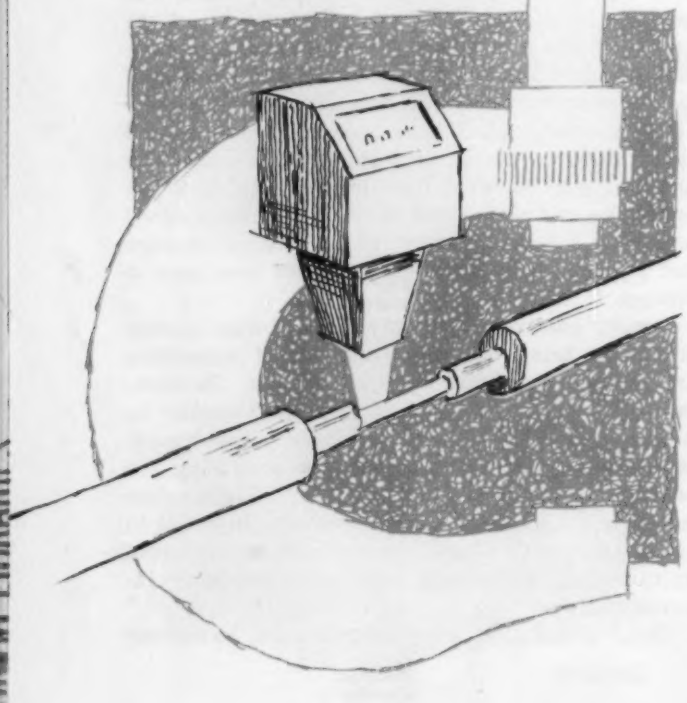
It is in the field of materials handling that some of the greatest strides are being made today. For years materials handling was considered out of the realm of the engineer's thinking. Carting materials around from one operation to another was considered more or less just a necessary evil. We know now, however, that this is a necessary evil. We know now, however, that this is a costly operation and that the more mechanical the operations can be and the less physical handling of materials, the lower the cost of manufacture. Furthermore, good materials handling lowers the amount of spoilage and raises the quality—usually with less time in process.

Quality control and maintenance of high quality standards bring us to the subject of measuring and recording instruments in automation. To maintain quality, one must know just what quality is. A standard must be set and then measurement taken to see that the equipment is producing the product according to that standard. This requires measuring instruments, and obviously, in order to have a record of what took place during the production day, we should also have recording instruments.

Those plants that are presently using measuring



MANUAL INSPECTION VS AUTOMATIC INSPECTION (AND CONTROL)



instruments and recording instruments will not experience a great revolution in their thinking when they go to automation. For those companies that make very little use or no use at all of either measuring or recording instruments (and there are companies today that fail to take advantage of these devices), they will have to change their thinking when considering automation. And in some cases where there is "art" involved and where there is a degree of employee's skill involved, not only will production people have to start using measuring and recording instruments, but in some instances instruments may have to be invented and devised to measure those so-called "arts". An example of that, of course, is where a worker touches, looks at, or smells a substance to determine if it is "just right"; whereas, if a standard were set and a measuring and recording instrument were devised, the manufacturer would not have to rely upon the worker's sensitivity, speed, or judgment, all of which normally vary from hour to hour and day to day. Instead, there would be quality consistency and uniformity.

As mentioned before—since automation is a new concept of manufacturing, the analysis of current production methods and equipment, materials handling procedures, and inspection techniques is one of the most important phases of the automation study; for it is predominantly in these areas where the new equipment and methods are being applied to produce the desirable results of automation.

▶ Analyze the Labor Force

The relationship of the labor force to automation is somewhat indirect as far as determining whether automation can be applied to a given plant. However, labor is a prime factor in production; therefore, we cannot overlook the qualifications and capabilities of the working force, how the workers can be adapted to or trained for automation, and perhaps of greatest importance, the attitude of workers and unions toward automation.

Unions, naturally, look askance at mechanization and automation developments, and whether they believe in the new developments or not, they must show concern for the welfare of members. Any employee whose company is considering automation is worried most about his individual job—what will happen to him—and rightly so. Therefore, it is management's responsibility to condition employees for automation and to explain its advantages; where they will fit into that program; and how they will benefit from that program.

It is significant to note that in all cases wherein companies have automated, employment has been increased. Now, why has this happened when on the surface it appears that automation would replace labor and thus decrease employment? This increase results because in automating, manufacturing costs are decreased which puts a company in a highly desirable competitive position saleswise. It is, therefore, able to sell more units, which requires more production, and this, in every instance—to the writer's knowledge—has brought about greater employment in those companies that have automated. Factory workers have benefited in other ways. Automation requires the use of the employee's higher skills and actually makes for a happier work day. That is, the work is easier. It is not as heavy and arduous, and not as dangerous as it was before. Furthermore, automation requires thinking, and it causes the worker to have pride in his work.

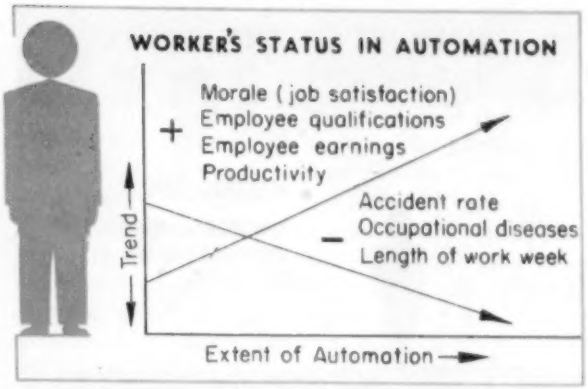
Of course, there will be temporary disruptions to labor forces during the brief adjustment period but this too, can be held to a minimum by proper planning. (This was proved at the close of World War II when there was a comparatively smooth transition from wartime to peacetime production.) When an automation line is installed, it is not done suddenly, overnight. Instead, it is a step-by-step development. During this time the employees will continue working on the old method while being schooled on the new. Then as the new method is installed, they will be ready to go to work on the new machinery and process.

The labor market and labor rates are expected to be affected somewhat by automation. With higher skill being required, the average hourly rate per worker will increase. On the other hand, individual productivity per hour will go up still greater; and, therefore, the unit cost of the item manufactured will go down. Employees of the future will require greater training and education. In fact, job standards have already started to rise to the point where in some instances today a foreman is

required to be a graduate engineer.

One of the past (and present) problems of the labor market—intermittent hiring and firing—will be lessened greatly. Automation will eliminate the need to add many workers to one task temporarily and then discharge those workers because machinery will be able to take up the slack or temporary increase in production. Therefore, suddenly being faced with the need for a large group of workers in a scarce labor market is not going to be as prevalent in automated production as it is at present. It will mean more stable employment.

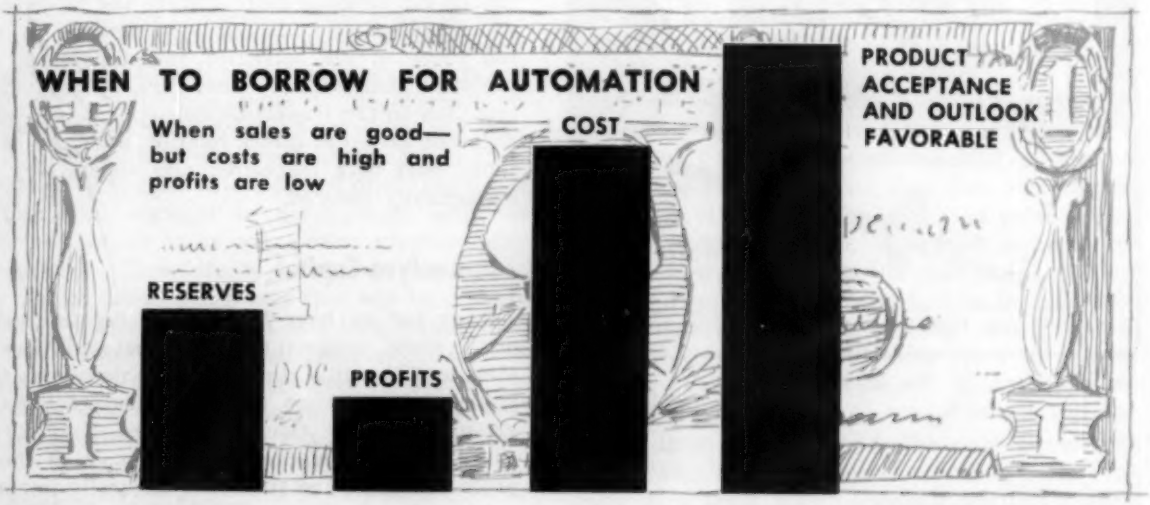
Obviously, if management explains automation properly to employees—the employees' morale will remain high, or become even higher. On the other hand, if it is not explained to the employees, dissatisfaction can be expected. There will be unrest and uneasiness. In fact, in some cases the misunderstandings have actually led to direct sabotage of management's efforts to install automated principles. Therefore, there are mutual advantages to be gained by properly explaining automation and taking labor into the confidence of management.



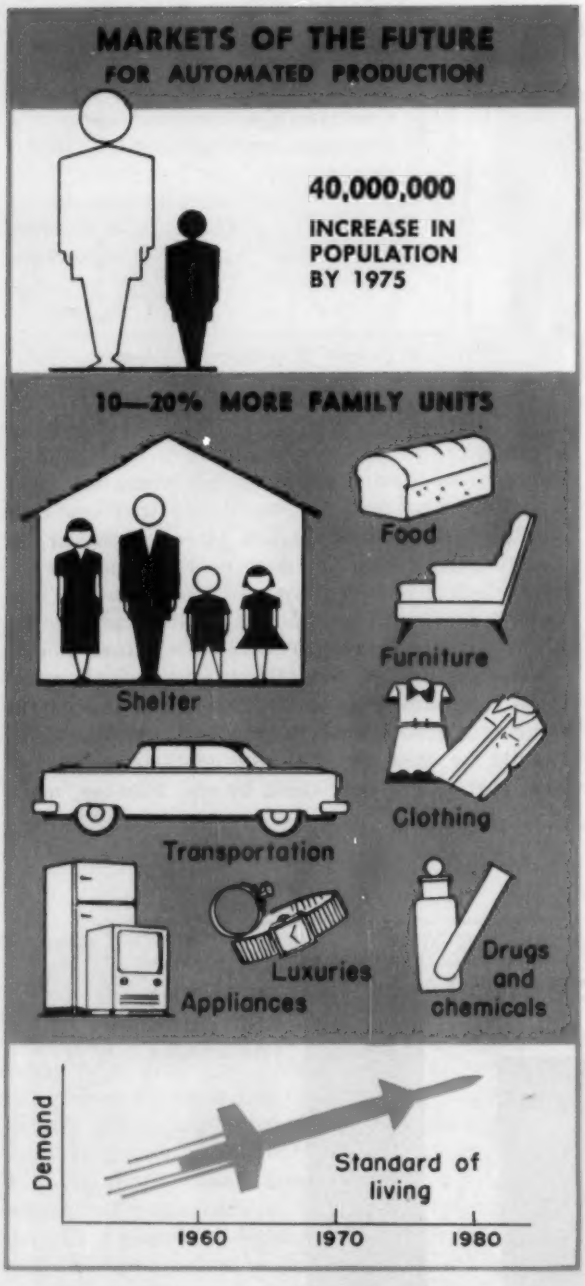
▸ Analyze Production and Labor Cost

In order to determine whether a company can or should automate, costs must be studied closely. First, we must compare the ratio of labor cost to material costs. Obviously, if labor cost is very high in comparison to material cost, then the predominant effort should be directed toward minimizing that labor cost by raising the unit productivity per worker hour. On the other hand if the material cost is much higher than labor, then emphasis should be on keeping rejects to a minimum by improving the efficient use of the material, or possibly by substituting materials. And this is where the latest engineering developments come into play.

In one case we found that a search for a new material had been made about ten years ago, and at that time no material was found that could do a certain job at an economic price. However, in subsequent years strides were made at such an accelerated pace that the survey of ten years ago was obsolete, and new materials were later found to be available and at the right price. Therefore, if materials costs are high it behooves us to look again at the materials that are available and the manufacturing methods used to process these materials. It could be that by changing material specifications, part of the cost could be cut. Further, manufacturing costs can be reduced considerably by keeping quality high, rejects low, and wastage at a minimum. This, of course, is one of the main purposes of automation.



Let us look at another cost problem—"transfer" losses due to manual handling of product between successive operations. These losses can be materially reduced by automatic handling with continuous processing methods rather than by batch methods. An example of the conversion from a batch method to a continuous method is the manufacture of mar-



garine with votators. This automation system has lowered costs and raised quality so that with this method it is now almost impossible to tell the difference between margarine and butter.

In continuous processing, not only are transfer losses reduced, but also production is more uniform. Too often in batch methods one batch is not like the previous batch or the next one; so losses due to non-uniformity are high. Yet, they can be minimized in automation—and this leads us right back to materials handling.

In automation the flow is continuous, and naturally, a good deal of materials handling is eliminated. Therefore, if there is labor cost in materials handling and it is high, that is a good place to consider cutting costs through automation. And, as indicated before, a by-product benefit will be reduced spoilage and waste.

Another cost factor to analyze is the relation of inspection costs (including supervision) to total labor costs; if inspection costs are high or supervision costs are high, it is probable that these costs can be cut considerably with automation because again primary results of automation are uniformity and high quality of product. In line with that, automatic inspection techniques can be installed to help cut down slow and costly manual inspection.

Let us illustrate the experience of one of our clients. Previously, peanuts were inspected individually and visually by a large group of workers for (1) discolored peanuts and (2) foreign matters. Now, with automatic inspection techniques, discolored peanuts and foreign matter are now automatically removed by a device that uses the reflection and variation of light principle. The results have been lower costs and better and faster inspection.

Another example is that of testing electrical circuits and sub-assemblies. Now, these can be tested automatically and the test circuit can also be changed automatically, thus eliminating the costs and delays of special test set-ups.

Supervision is also reduced with automatic inspection methods even though at first glance it may appear that more supervision will be needed. With better records furnished more speedily, decisions can be made more quickly and more tenably which allows one inspection supervisor to widen the scope of his activities and understand more problems than before. Therefore, by applying automation to the inspection department, supervision does not go up in direct relation with the productivity, and both inspection and supervisory costs are actually lowered.

▷ Analyze Capital

Thus far we have been discussing the analysis of the plant, product, facilities, cost and labor situation and how this study can help determine if and how automation can be applied successfully in a given company. Once indications point to possibilities of automation, then the cost of the program and source of funds are naturally important.

First, the company's financial strength and condition must be analyzed. The trend of the company's financial health should be plotted over the past years with particular reference to manufacturing costs, earnings, and the trend of reserve funds, which can be a major source of capital for an automation development program.

If the company is in a strong position with substantial reserves and a good earning record, the type and scope of the automation program will be limited only by the funds available. On the other hand, if a company has been weakened by losses or fluctuating earnings and reserves for future improvements thereby adversely affected, then it may be that a partial automation program, on a limited

basis, will be the answer. In other words, the type of program which is finally set up will be governed by what the company can reasonably handle without impairing its financial health.

In the event a company's financial reserves are greatly limited, this does not mean that it should not consider an automation or partial automation program. As a matter of fact, the study may reveal that automation is the answer to the problems which have caused the weakened condition. In such a case, it is certainly advisable to consider borrowing capital for an automation program.

Often times, losses are due to high operating costs. Therefore, since one of automation's greatest benefits is that of lowering costs, a company with the problem of high costs cannot afford not to do everything possible to lower costs if it wants to stay in business and strengthen itself for the future. Seeking additional funds for a cost reducing automation program of this nature would be very much justified. The form that this borrowing or raising added capital would take, such as a stock or bond issue or a direct loan from financial institutions, would naturally depend on the circumstances in each individual case.

The important thing would be that the automation program be planned so that high cost operations would be automated first for more rapid amortization of both the cost and any incurred indebtedness.

There is one other financial benefit to be derived in carrying out an automation program and it may help to lighten any financial burdens that the automation program poses. That has to do with latest tax provisions. In order to encourage research and development by private industry, the Government has taken a liberal viewpoint toward the expenditures of funds for these purposes. In fact, the latest laws give special write-off and other privileges to companies engaged in development work of which part or all of an automation program may be classified. Therefore, in most cases part of the costs can be handled in a way that will benefit the company. Since application and interpretation of the law varies with the individual situation, the company's tax and legal departments can set up the details of costs and write-offs that will be best for the company in the long run.

▸ Analyze Your Future

No company can or should embark upon any automation program without taking a look into the crystal ball of the future. Although we cannot foretell exactly what will happen, nevertheless, there are various sign posts and indicators which reveal what might reasonably be expected. These are based upon research by both the government and private industry. For example, it is known that under normal conditions, the buying population of the U. S. will increase considerably by 1960 as a result of the high birth rate since World War II, plus greater longevity of our older citizens. And, this growth will continue so that by 1975 the total population of the country is expected to be over 200 million individuals.

Further, starting in 1960, there will be a sharp increase in eligibles for marriage and establishment of new homes. These and other indicators will help a company to analyze the trend of its recent and current sales and compare them with what might be expected five or ten years hence.

This analysis must take into consideration possible future demand for the present product—that is, whether demand is likely to increase, whether new or substitute products may be expected to provide new competition, or whether the product may just naturally become obsolete the same way that the ice box gave way to the electric refrigerator. Obviously, if there is any question about the customer acceptance of the product within the next five years or so, that would influence the consideration of an automation program.

Another factor to consider is the relationship of prices to sales. If a company is not getting its share of the market, it may be due to the prices of its products. In other words, let us assume that quality may be high, but because of high manufacturing costs, the product is priced over a good portion of the market. If it is the company's desire to widen the market and increase sales, it can do so only through lowering the sales price. This means that a broad automation program of reducing total and unit manufacturing cost should be considered. Or, it may be found that in looking into the future, increasing competition will force prices down. In that event it may be wise to plan an automation cost reducing program just as insurance toward maintaining the company's future competitive position in the market.

Not only are prices, markets, competitors, etc., important, but as we all know, the final test is net profit. That is the fundamental purpose of all commercial enterprises. Therefore, in analyzing the future, it must be done in light of potential and desired profits. Actually, all of the analyses discussed above will supply the answers as to what sales and profits can be forecast in the next five or ten years barring a national emergency, of course. The company will know what its market will be, what its production will be, and most important what its costs and capital outlay will be.

That is why all of these factors must be analyzed before launching an automation program. The company must know with reasonable assurance where it is going, how it will get there, what the trip will cost, and what the rewards will be at the destination.

Certainly, the time, effort, and expenses of a complete automation appraisal or analysis will pay for itself many times over. No longer can business operate on a guesswork basis. To keep pace with the development of Automation Production Systems (APS) of the future, management must think and work with facts to be certain of preserving its present achievements and enhancing its future competitive position. That's why the far sighted executive is interested in determining now if his company is ready for automation and its many benefits.

Use of machines to assemble the company's products requires preparation to meet the problems of machine selection, department layout and production scheduling to best utilize the potentials of the equipment and personnel involved

Part 2

PLANNING FOR AUTOMATIC ASSEMBLY

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HAVING CONSIDERED the introductory aspects of assembly by automatic machines from the broad outlook of the development of the art, it is well to next look at the elements of planning required to get established and operate a department of such machines. Potential in terms of establishing a machine assembly department will very materially change all hand assembly department production ratios.

Planning for a machine assembly department requires treating the whole subject as a new and distinct department in relative and comparative status to that of setting up a lathe department, grinding or milling department and of providing for all of the basic essentials to that art and know-how that will assure its full practical production success.

Original data necessary to formulate this planning is derived from the company's study of products. The analysis of products for assembly by machines will show the number of components; the volume of the lot produced at one time; the number of lots produced per year; the variations of any one product in change of one or two parts or of paint, color, capacity or coding and the volume of each produced at a time; the range of sizes of a product and its similarity of part size for simplicity of tooling; the costs of handling of each lot; the costs of inventory of each lot; and the shop operators used regularly or intermittently.

Machine Selection

Top management has a real problem in recognizing the different types of automatic machines for assembly to meet the type of product and method of manufacture in its own shops. In general the following classifications may be helpful for a relative and comparative reference in initial analysis of assembly problems.

One of the early developments in mass production assembly made use of the long center bench with operator positions at either side. Products being assembled had parts added at each station and partial assemblies were passed from hand to hand with the bench taking up all slack as time per unit varied or as downtime trouble developed at any one operator's station. These lines are common to almost everything from watch parts through vacuum cleaners, motors, sewing machines, electric, electronic and radio assemblies. Hand operations on arbor presses, riveters, foot kick presses, solder joints, etc., were added to these lines as operations required and as know-how was developed from experience.

Just before World War II the trend to the moving belt in the center of this long bench became popular. With it came "group" or "team" type of assembly where a given number of operators kept an even-paced rate of production with the slow movement of the conveyor belt. When parts

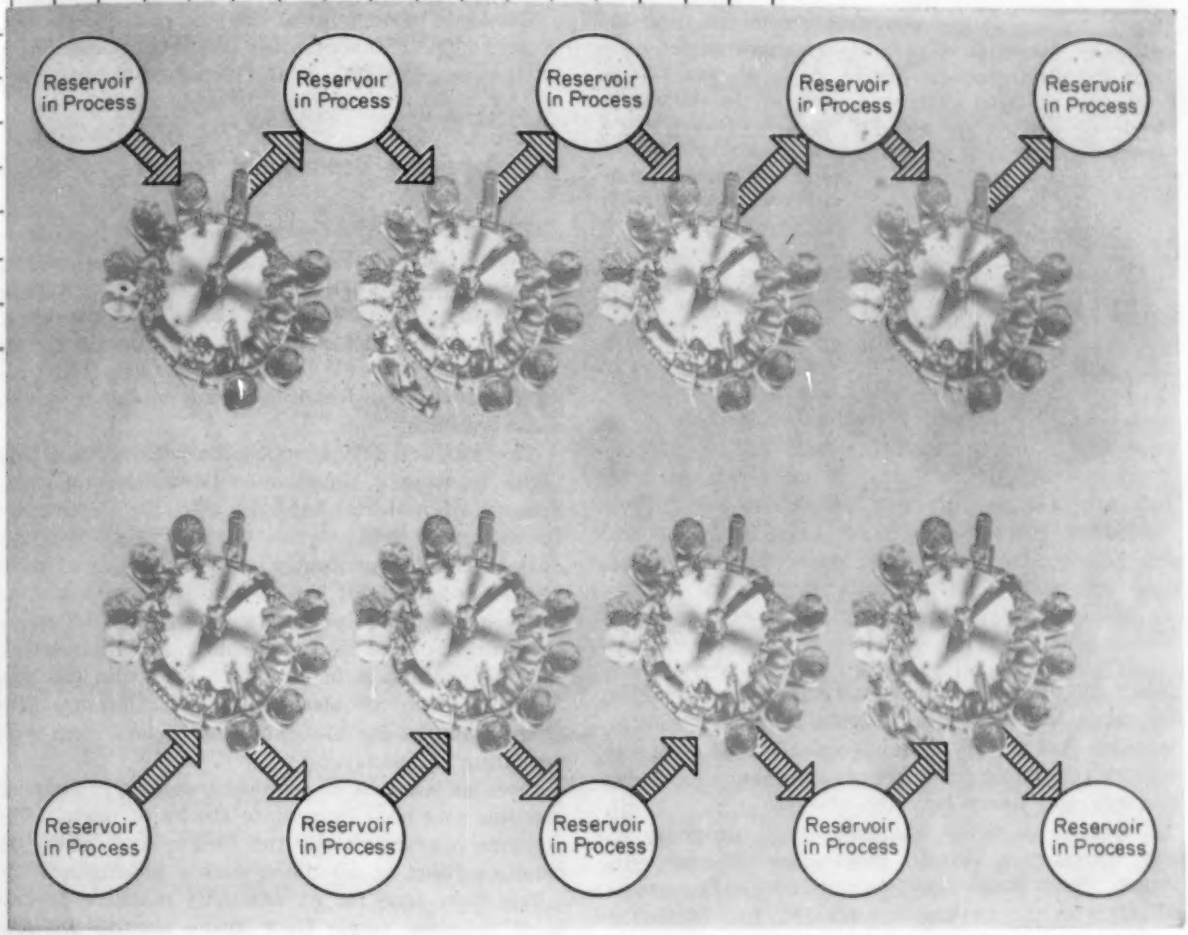


Fig. 6—This represents a typical type of automatic assembly department with a battery of machines. Each may be engaged on entirely different products or may be tied together with work-in-process reservoirs as indicated. For very short-run service some of the machines may have all tooling removed using work nests only for hand-fed assembly by a series of operators sitting at each station

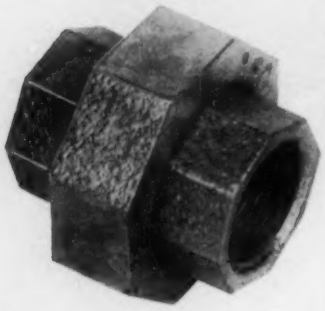
in process were "off tolerance" so that they did not go together within the regular unit of time, immediate trouble developed requiring space to put parts; or the shutting down of the entire group. Quality control took on major importance for a rigid degree of uniformity with all products coming to these production assembly lines. The salvage department came into a greater degree of importance to reassemble, salvage, repair or scrap all units taken off the lines in an incomplete status.

After World War II the trend toward a precision degree in machine assembly lines began to appear where units of machines, such as drillheads, tappers, riveters, etc., were put at operator stations at some parts along a moving chain. These machines became known as straight-line machines as they followed the know-how of the central moving belt line but were given intermittent motion with stopping of the chain for the work cycle. In the past few years, probably somewhat under 100 such machines have been placed in automotive plants. To change from one type of assembly to another these machines have to be returned to the shop to be rebuilt with a major shutdown period for the duration of the model changeover.

Modifications of the straight-line machine are coming into being for single-purpose service where 60 to 90 stations are on one line. Parts of this line will have groups of hand operators to do work considered too complicated for machine assembly; also to take over where a machine station fails by continuing with hand work instead of shutting down the entire line. Downtime is extremely serious on this type of line which requires providing for two deep in all facilities to back up every operation with a skilled worker whenever needed.

Another approach to a fully successful form of automatic assembly exists in the assembly machine tool. By machine tool is meant a general-purpose machine, such as a multiple-spindle turret lathe or multiple drilling and tapping machines, which can be tooled and retooled quickly for everything desired to be produced upon them. Here tooling attachments to perform the needed assembly operations are placed on the machine for each job to be run. Complete changeovers from one to an-

Fig. 7—There is an enormous field in automatic assembly of many thousands of product items such as the common standard range of various types of pipe unions. Although normally using only four to six stations to assemble and deliver one unit, such a product would normally be set up on the machine with two sets of tools for double production. Machine tools for assembly will handle a wide range of sizes with little tooling change



Courtesy Ward Foundries, W&K Mfg. Co.

other set of tooling are practical. This provides the shop with a fully flexible, always available machine tool for all production needs that does not require rebuilding for different assemblies or model changes and never becomes obsolete.

There is in every analysis of all products of any company a certain percentage of small-run items. Such items may not fall within the range of attachment tooling investment for assembly machines yet require machine handling. The majority can be most effectively handled by paced machine assembly on a machine without automatic attachments. These are replaced by operators with boxes of parts. This type of stripped-down machine uses a large diameter table for ease of operator assembly and does not have any feeders, tooling attachments or program controls. This machine can, at any later date, be made into a fully automatic machine. Its purpose is solely to provide an instantly available assembly machine for short runs that has no setup time other than to change work station nests. Machine assembly is fully practical down to lots of 500 to 1000 assemblies at one time with this type of machine. Two different products may be assembled on the machine at the same time.

Still further in analysis of company products and volume range is the ever-present portion where the assembly requires only a few stations; say less than four. Such simple assembly problems are most satisfactorily handled without an assembly machine but by making use of the high production rates of highly efficient single machine assembly tooling attachments. They can be set individually on straight line benches with operators serving progressive feeding from one to another station in a form of paced assembly. The fast rates of tooling attachment feeding make this method highly attractive for the minor assembly problems of a complete automatic assembly department.

This is a basic point of the analysis; to select the proper type of machine for assembly of all classes of the company products of small or large volume.

▶ Assembly Department Layout

The layout of the floor plan for an automatic assembly department should start from the analysis of all of the company products as to the type of machines to be used, the length of each run for its effect on the tool crib and setup facilities, the stock rooms of parts to be machine assembled and of the stock room for finished assemblies or partial subassemblies.

The productivity per operator will increase from eight to twenty times over hand assembly. The amount of material brought into the department for assembly will require careful floor plan layouts to make a constantly available supply of parts always accessible at the assembly machine so that its operator, or helper, may readily fill the magazines or hoppers used in feeding. Where the assembly machine is in two-shift operation this material handling problem takes on still more of a study problem for assurance of highest degree of operating efficiency.

Circular benches, in segments, can surround each machine and hold immediate stocks of parts. The machine operator keeps the feeder hoppers on the machine filled at all times during production.

The floor plan for an assembly machine department requires ample floor space around the machines to permit the parts supply trucks to bring parts to the assembly machine benches and to take away finished assemblies, waste, etc., without disturbing operations. The same amount of floor space between the assembly machine and the circular parts box benches should be provided for the

TYPICAL SEQUENCE TOOLING FOR STANDARD PIPE UNION

(40 to 60 per min.)

Station #1—Feed threaded Half Union and orient to position at Station

Index Station #2—Feed Plain Half Union and orient to position atop the other half at Station

Index Station #3—Feed Union Nut and orient down over the Plain Half Union at Station

Index Station #4—Align and drive Union Nut to complete assembly

Index Station #5—Deliver to container or box
Index

Fig. 8—The pipe union illustrated in *Fig.* 7 would normally use a sequence tooling as indicated here. Each part would be placed directly into its proper position in the work nest of the machine tool by a simple straight-line motion of a feeding attachment properly suited to the type of part being run with full protection of threads or other sensitive edges or surfaces

TYPICAL SEQUENCE TOOLING OPERATION FOR COMMON CAN OPENER

(30 to 40 per min.)

TABLE #1 (horizontal)

Station #1—Feed handle from hopper into nest

Index Station #2—Feed first washer from hopper onto handle prong and orient washer to seat

Index Station #3—Feed spacer washer from hopper onto handle prong and orient washer to seat

Index Station #4—Feed body from hopper into nest

Index Station #5—Feed the feed wheel from hopper onto handle prong and orient to seat. Also orient radius side of feed wheel against body (done at hopper)

Index Station #6—Stake the handle assembly

Index Station #7—Feed blade onto body and orient for proper position (done at hopper)

Index Station #8—Feed rivet into hole in blade and body and orient on feed track

Index Station #9—Spin over end of hollow rivet

Index Station #10—Transfer assembled can opener to the second Table Station #2—also turn over 180 degrees for proper position

TABLE #2 (horizontal)

Station #1—Feed mounting card onto position from card feed magazine

Index Station #2—Receives can opener from Table #1 Station #10 at proper location for mounting

Index Station #3—Staple can opener to card

Index Station #4—Deliver can opener mounted card to chute or counter as provided by client

Index

Fig. 9—Products, rarely thought of, such as the common popular can opener are produced in sufficient volume to make assembly by machines very attractive. Here is a division of sequence tooling for assembly where a second machine table carries the balance of stations. This application might be effectively placed on two 8-station machines; one 12-station and one 8-station, or one 16-station machine should a manufacturer's range of products show any one model of machine to be the preferred size for his shop uses

short-run machine to give ample room for the operator's stools and for passing space.

If the runs are of small-lot duration requiring frequent tooling attachment changeover on the assembly machine the floor space at the machine must be carefully laid out to provide room for the tool removal wagon taking attachments away from and to the machine. A storeroom or cribroom for tooling attachment storage of these valuable mechanisms, and for their maintenance or trial testing with fixtures before each run, is an essential part of an automatic assembly department.

Where product assemblies require use of several machines, the floor space layout must recognize the importance of full space allowance for floating work reservoirs or partial assembly stock-in-process problems. Floating work reservoirs are designed to take parts from one machine and deliver to the next machine for continuous group operations, or to enable the stacking of parts-in-process whenever downtime, lack of parts or off-tolerance parts prevent continuance of machine assembly.

▶ Planning Assembly Schedules

Generally most modern production control techniques developed for mass production are applicable to automatic assembly departments. The problem of material inventory control is often more complicated than for machining operations since all of the component parts must be on hand in sufficient quantity in order to complete or continue production assembly runs.

The best production may be realized with the minimum of machine tooling changeovers. Studies generally show where enormous savings may be actually realized by doubling or tripling the volume of a given run on a product to eliminate so much multiple porter service, box handling, stock paper work, and an enormous amount of setup time.

The time of three hours for tooling changeover may be taken as a reasonable average for rearranging machine setup from production of one product to another. The schedule of the setup crew for taking tools from the tool crib to the machine and return, the condition of the attachments, and the complexity of the operations have much to do with efficient tooling changeovers.

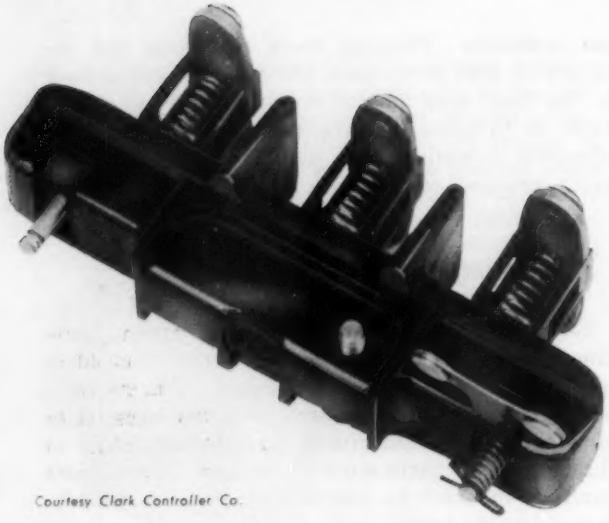
Should this setup handling be efficiently established at any given shop, much may be scheduled at the end of the production day, week or month that will contribute greatly toward the longest practical run of a given product at one setup time.

▶ Operational Problems and Personnel

Years of experience with fully automatic and continuous special machines and machine tools in regular volume production service clearly show that after a new machine is fully debugged and put into service, more than 95 per cent of downtime will be due entirely to off-tolerance or off-specification parts.

It is clear that these mass-production machines go through their cycles of operation from 10,000 to 25,000 or more times each day shift while the parts being assembled pass through the machine only once. Suspecting parts as the source of trouble is therefore a reasonable assumption in quick trouble shooting by the operating staff.

It is essential that the machine assembly foreman and the manufacturing superintendent establish two sets of control parts to be kept on hand. A set of parts is desirable for "control sample testing" through the machine in case trouble of complicated nature develops necessitating removal of current running parts for a few moments. The control samples are always promptly returned to the *Control Stock*. It is desirable that control samples al-



Courtesy Clark Controller Co.

Fig. 10—Here is a particularly fine example of progressive station automatic assembly where different similar parts are added at different stations to provide the best balance of the minimum of assembly time at any one station on the machine tool. Note as well it is possible by this product design to assemble practically from three sides of the product without moving the parts in the work nest of the machine tool

TYPICAL SEQUENCE TOOLING FOR 3-POLE STATIONARY ARM CONTACT

Station #1—Magazine feed mounting screws into Work Station Nest

Index Station #2—Operator hand feeds the Main Body placing on side or vertically as may be finally determined

Index Station #3—Magazine Feed and orient the spring into Work Station and actuate holddown

Index Station #4—(Same but at different location)

Index Station #5—(Same but at different location)

Index Station #6—Magazine feed contact, orient and push down and over into position and withdraw holddown

Index Station #7—(Same but at different location)

Index Station #8—(Same but at different location)

Index Station #9—Magazine Feed and orient Auxiliary contact into Work Station

Index Station #10—Magazine Feed, orient and holddown the Auxiliary Contact Spring

Index Station #11—Compress Spring and lock with Magazine Fed Clip

Index Station #12—Magazine Feed Mounting Screw, Lock Washer and Lock Nut orienting and delivery to Work Station Location

Index Station #13—Electrical Tests if any or Delivery to chute or directly into container, tray or conveyor

Index

Fig. 11—Here is a typical sequence tooling study for the standard type of 3-pole connector as shown in *Fig.* 10. This is about an ideal number of parts to normally try to assemble on one machine of a 16-station model as it allows for "breathing", an essential requirement in machine assembly production operations. A set of tooling attachments could be arranged to permit assembly of a two or four-pole connector as well as this 3-pole connector

ways be dipped, colored, marked or otherwise coded so that they cannot become lost.

Automatic assembly machines are usually provided with complete interlock and safety controls that stop the machine and show by a lighted bulb on an operating panel exactly where each trouble spot may be the instant it occurs. Downtime is kept at a minimum by providing jogging switches around the machine and at attachments for immediate operator use.

Cleanliness and end-of-day cleaning by air blast, are important "must" essentials to successful operation of any assembly machine. Operating care is essential against the dropping of foreign matter into feeding hoppers or bowls.

With regard to personnel, an automatic assembly machine department will require the use of skilled multiple-spindle machine tool type of operators capable of the safe handling of valuable machines under their care and of unskilled worker helpers for the handling of part boxes and assemblies to and from the machines.

At some stations where hand assembly may be specified to avoid over-complicated tooling attachments, the semiskilled worker will be fully effective.

In cases where an operator may have charge of more than one machine, the use of one helper at each machine will be found to be generally satisfactory, subject of course to the type of machine assembly in production. The supervisor, or group leader type, capable to keeping a "team" attitude among the workers is of prime importance in mass-production work.

The production from machine assembly will definitely be no better than the type of operator or group leader selected and given charge of the machine. This means, to spell out exactly in detail, that net machine production can vary from 50 to 85 per cent of machine operating efficiency with 50 to 15 per cent downtime. The downtime in this range being entirely needless with proper operator incentive and group spirit.

When the proper operator, selected for operation of these multiple-station assembly machines, is given charge of operation for production, all the skill of team player is put into service to watch everything all the time; otherwise downtime will result. Such machines, being thoroughly provided with circuit interlocks, will shut down whenever anything goes wrong with the circuits. They do not cover, however, the other factors that the operator must watch continuously.

The operator must see that all feeding devices are kept loaded with parts being fed to the machine and that individual stations do not jamb. Nests can be easily clogged by off-tolerance parts or through foreign matter mixed in with the parts or through lack of complete cleanliness. Trouble may occur at the feeders, at the stations or in pressing operations, and in parts failing to assem-

ble properly, requiring stopping of the machine, removing, cleaning out of parts from feeder, track, orienting and escapement devices and again loading with proper tolerance parts before the machine may be again started.

Operating technique requires the attention of a person skilled in keen watchfulness for all details of his machine for best daily production results. The natural operator learns to know of coming trouble or need of attention by the slightest change of sound of his machine. This skill for the successful assembly machine is no more than that required of the multiple-station turret lathe operator, or multiple-spindle grinding or tapping machine operator. It is a matter of recognizing the qualities required for the job for guaranteed success.

Training to use the new operation of machine assembly, is of equally vital importance. We all know from past war emergency experience, that trained supervisors and operators for vital turret lathes and similar machines, just were not generally available.

Here is one operation where incentive for the right type of operator is worth consideration. Setting the base rate for the successful level of productive machine operating time with an ever increasing incentive for the operator for increased percentage above that amount is one way that may assure most uniform production and keep downtime to the lowest practical minimum. Automatic assembly is an operation which can be particularly sensitive to operator cooperativeness. This should never be taken lightly or forgotten by any management.

Assembly machines provide a new technique, fortunately mostly of common sense, that requires the attention of top management everywhere to see that balanced training is provided for all. Not only should skilled foremen and operators be trained in automatic assembly, but methods engineers and particularly design engineers are vital, to assure its proper application and use. The design engineer can make or break an otherwise profitable manufacturing operation by careless design of parts that do not go together easily and require prohibitive tooling costs to permit manufacture at all.

Design considerations of automatic assembly will be the subject of the next part of this series to appear in the next issue.

TYPICAL SEQUENCE TOOLING FOR COMPLICATED INSTRUMENT BASE

(30 to 40 per minute)

Station #1—Feed two "Pins for Ground Straps" into nest locations at Work Station on elevating holders

Index Station #2—Operation hand feeds "Base", using slots with orientation pilot fixture pins at work nest, over "Pins for Ground Strap" at Work Station locating for drilled hole outward

Index Station #3—Feed two "Ground Straps" by separate Feeders or Magazine onto "Base" locations at Work Station. Bring down locating fixture through hole in "Ground Strap" into hole in "Pin" and elevate "Pin" through "Ground Strap" to final location. Then raise locator for free index

Index Station #4—(Idle for the moment)

Index Station #5—Stake (with style G stake tool) both "Ground Straps" at Work Station with "Pin" backed up on solid support fixture

Index Station #6—Feed "Filter" at Work Station using locating pin of retracting type fixture

Index Station #7—Stake (with style G stake tool) the "Filter" from underside at Work Station with upper back support pin

Index Station #8—Feed "Hanger" from formed magazine with bottom feed guided into slot (with holddown)

Index Station #9—Feed "Hanger Rivet" and push into place in "Base" at Work Station

Index Station #10—(Idle for the moment)

Index Station #11—Rivet (with style G tool) the "Hanger" from underside of Work Station

Index Station #12—Feed from Formed Magazine one "Test Terminal" to off center location onto "Base" at Work Station

Index Station #13—Feed from Formed Magazine one "Test Terminal" to off center location onto "Base" at Work Station

Index Station #14—Stake (with style A 6 point tool) one "Test Terminal" from underside of Work Station

Index Station #15—Stake (with style A 6 point tool) one "Test Terminal" from underside of Work Station

Index Station #16—Feed "Test Terminal Strap" from Magazine Track onto "Test Terminals" at "Base" at Work Station with hold down clamp

Index Station #17—(Idle for the moment)

Index Station #18—Feed and Drive "Brass Test Terminal Screw" to fasten "Test Terminal Strap"

Index Station #19—Feed and Drive "Brass Test Terminal Screw" to fasten "Test Terminal Strap"

Index Station #20—Drill Hole in "Base" at outer rim

Index Station #21—Deliver to chute or container

Index Station #22—Vacuum Work Station clean for next cycle

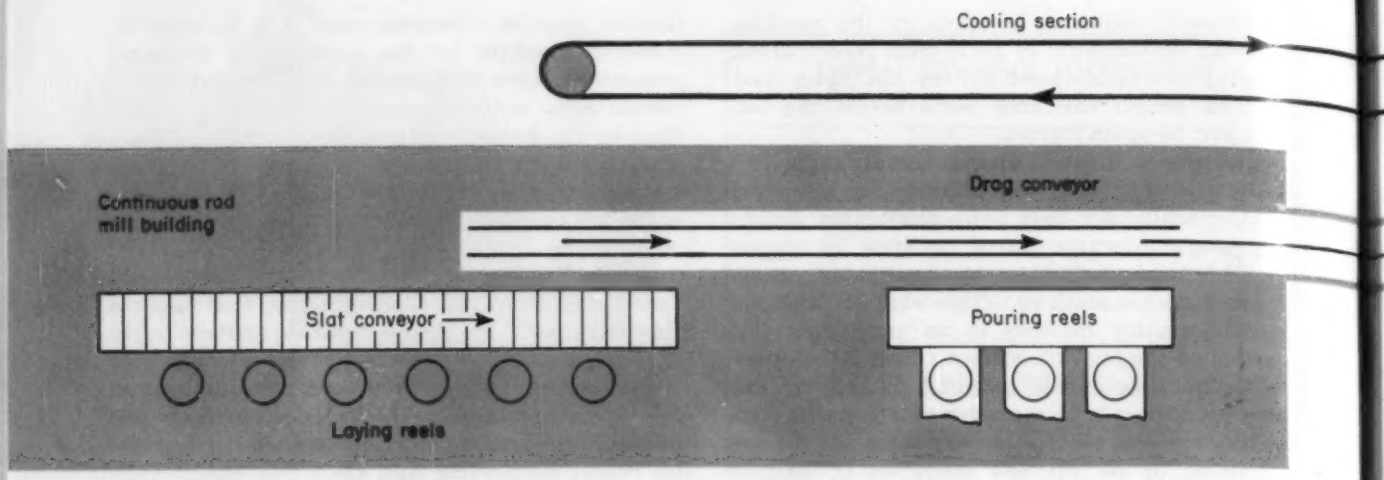
Index Station #23—Cement Stamp for "Cork Seal Gasket" in "Base"

Index Station #24—Wind cork gasket and deliver into "Base" gasket groove

Index Station #25—Deliver to chute or tray

Index

Fig. 12—This product, not illustrated herewith, covers an effective tooling sequence for the assembly of a 9-inch diameter plastic plate for an electrical instrument with a great number of parts. The first step is to assemble all the terminals and first needed holding parts. This application would, in final tooling sequence, be placed on two standard 16-station machine tools for machine assembly. Note the idle stations used for "breathing" in effective machine assembly



CONVEYORS ADVANCE

ROD COIL HANDLING

Realizing the greatest return from an investment in conveying equipment involves a studied consideration of how best to employ the available forms to utilize qualities of each—and just as important—the potentiality in integrating the conveyor system into production operations to do more than just move parts

SOLVING the problem of how best to automatically convey a given item does not always involve making an absolute choice of one form of conveyor over another. Condition of the item to be moved, distance of travel and existing plant layout are typical factors which can dictate the use of several different forms of conveyors in one integrated system for the best engineered handling of an identical item in various parts of a plant.

Conveying system, designed by Jervis B. Webb Co. for the Continental Steel Co., for the movement of coils of rod from coiling machines to storage point involves successively a slat conveyor, drag conveyor, and overhead hook conveyor, *Fig.* 1; it provides an example of the successful use of several conveyor forms, the means of transferring items from one type of conveyor to another, and the use of a conveyor in production to provide a moving storage line during a cooling operation. Product being conveyed is coiled rod which is destined to provide raw stock for wire drawing mills. These coils are formed by the continuous feeding of hot rod into laying or pouring reels. Laying reels, used for smaller diameters, feed rod in a circular motion to form the coils. In pouring reels, used for larger diameters, stock is fed from a stationary pipe into a rotating finger spindle in a pot to form coils. Completed coils—3 ft 10 inches in diameter, 1 ft in height,—weigh approximately 630 lb each.

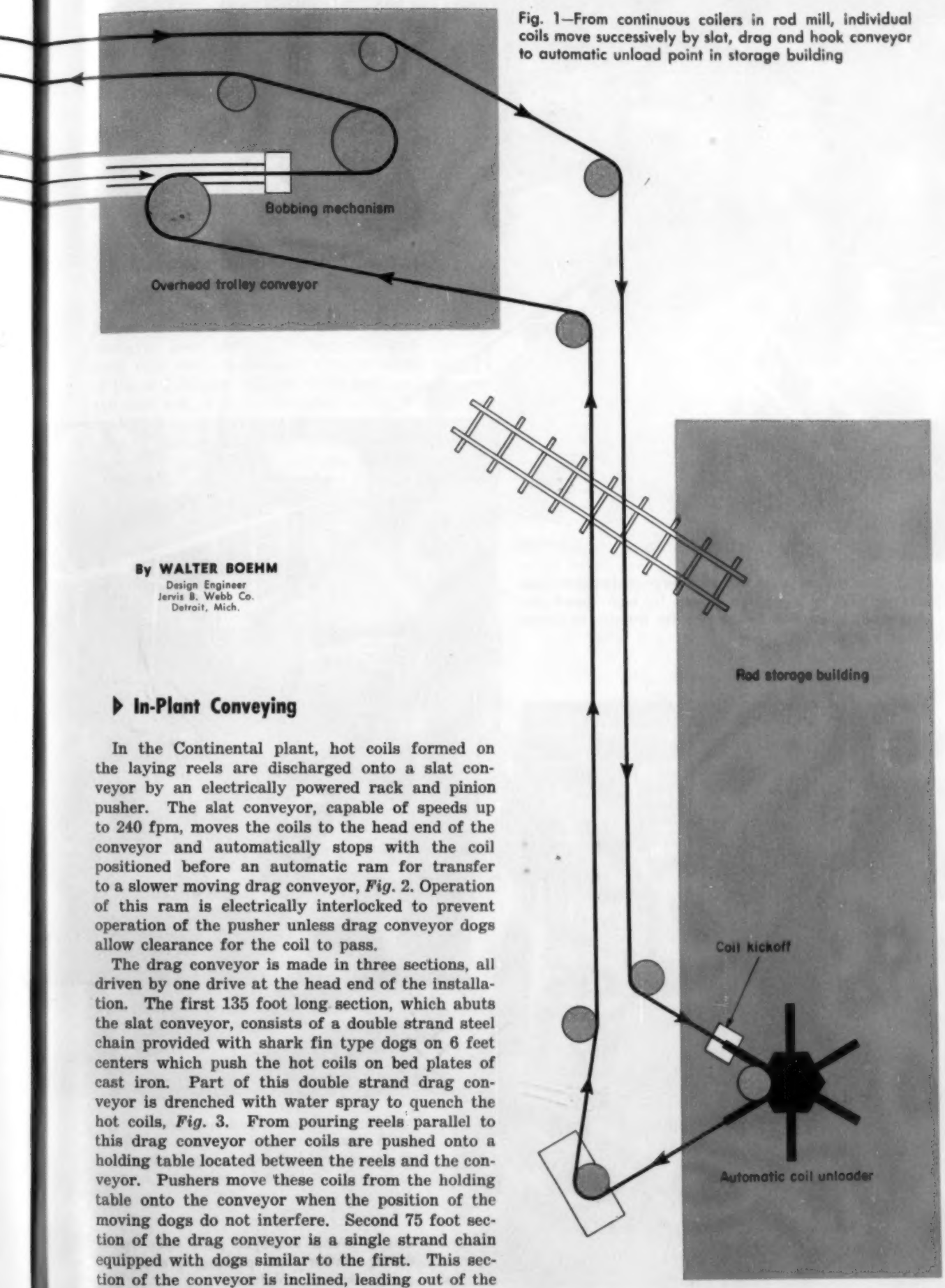


Fig. 1—From continuous coilers in rod mill, individual coils move successively by slat, drag and hook conveyor to automatic unload point in storage building

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▶ In-Plant Conveying

In the Continental plant, hot coils formed on the laying reels are discharged onto a slat conveyor by an electrically powered rack and pinion pusher. The slat conveyor, capable of speeds up to 240 fpm, moves the coils to the head end of the conveyor and automatically stops with the coil positioned before an automatic ram for transfer to a slower moving drag conveyor, *Fig.* 2. Operation of this ram is electrically interlocked to prevent operation of the pusher unless drag conveyor dogs allow clearance for the coil to pass.

The drag conveyor is made in three sections, all driven by one drive at the head end of the installation. The first 135 foot long section, which abuts the slat conveyor, consists of a double strand steel chain provided with shark fin type dogs on 6 feet centers which push the hot coils on bed plates of cast iron. Part of this double strand drag conveyor is drenched with water spray to quench the hot coils, *Fig.* 3. From pouring reels parallel to this drag conveyor other coils are pushed onto a holding table located between the reels and the conveyor. Pushers move these coils from the holding table onto the conveyor when the position of the moving dogs do not interfere. Second 75 foot section of the drag conveyor is a single strand chain equipped with dogs similar to the first. This section of the conveyor is inclined, leading out of the

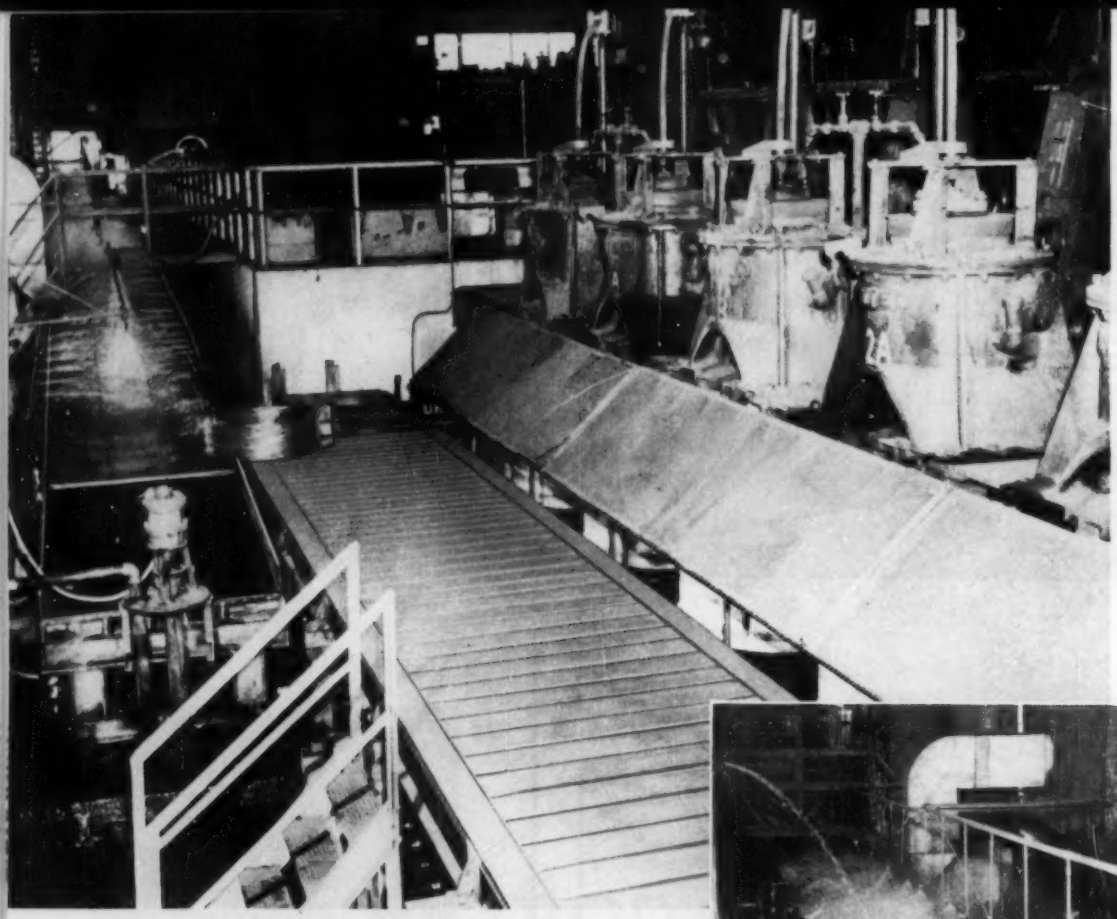


Fig. 2—Coils of rod, automatically discharged from laying reels at right, are moved by high speed slat conveyor to position before ram for transfer to slower drag conveyor

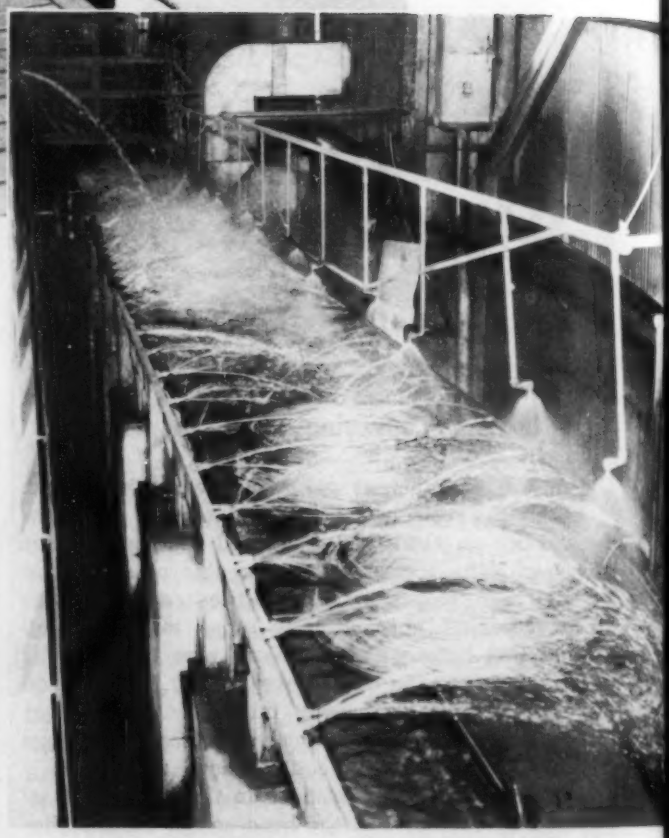


Fig. 3—Hot coils are quenched by water spray on first section of double chain drag conveyor

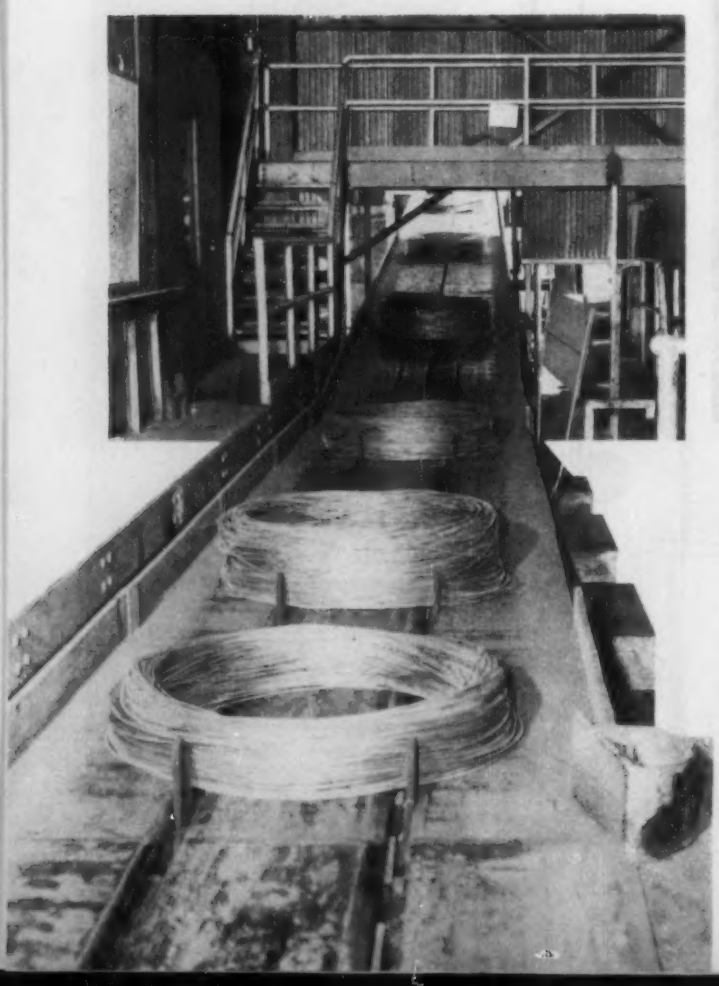


Fig. 4—Single strand conveyor pulls coils up incline. Pulling, rather than pushing, prevents excessive deformation of coil form

rod mill toward an elevated exterior point at which eventual transfer to a hook conveyor takes place, *Fig.* 4. Change from double to single dog, which pulls coils by engaging inside diameter of a coil, simplifies exchange from horizontal to inclined conveyor and by changing from a pushing to a pulling action holds deformation of the circular coil form to a minimum. Third section of the drag conveyor reverts to a double strand and pushes coils 30 feet to the point at which transfer to a hook conveyor takes place.

Movement To Storage

Transfer mechanism consists of a heavy pivoted bobber actuated by a cam mounted on the drag conveyor head shaft. Bobber tilts and lifts the back of a coil; as soon as a hook enters the eye of the coil, bobber will return to position to receive the next coil, *Fig.* 5. Synchronization of drag and hook conveyor is obtained through a mechanical tie of chain, gearing and shaft coupling. Hook conveyor is a conventional overhead trolley conveyor with wheels supported by I-beam track. Individual hooks are suspended from a load bar con-

Fig. 6—Each hook is equipped with camming rollers which cause hook to tilt when receiving and discharging coils

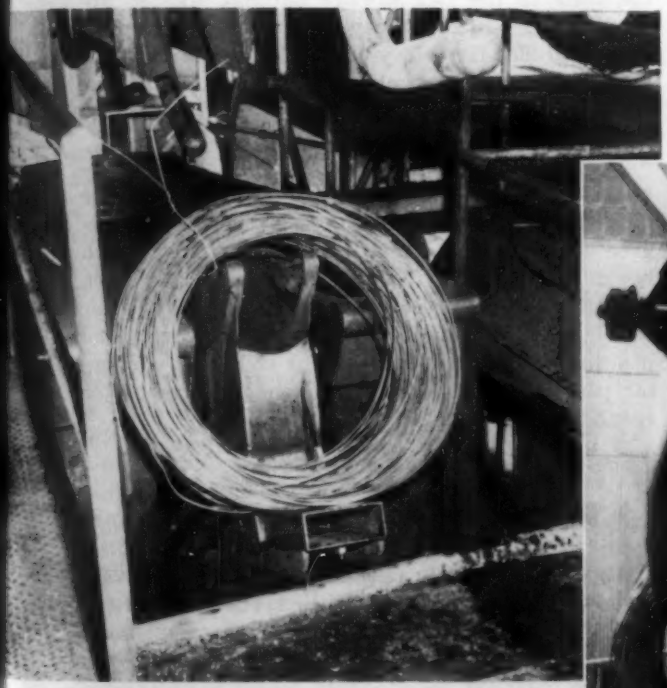
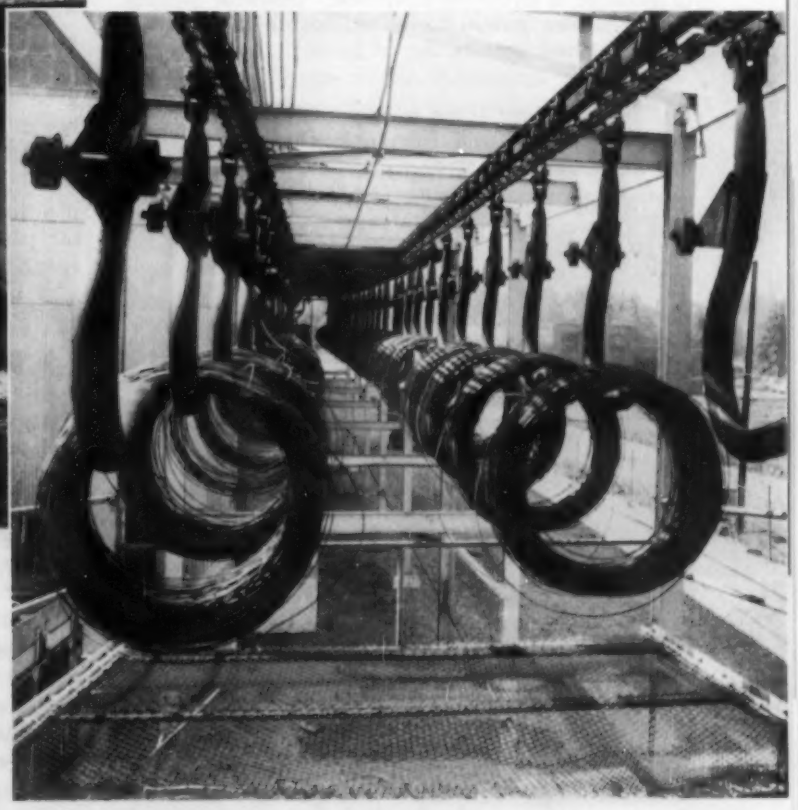


Fig. 5—Automatic bobber positions coil for transfer to overhead hook conveyor. After hook enters eye of coil, bobber returns to position to receive next coil

Fig. 7—Hook conveyor travels through extra 400 foot run to provide cooling of coils



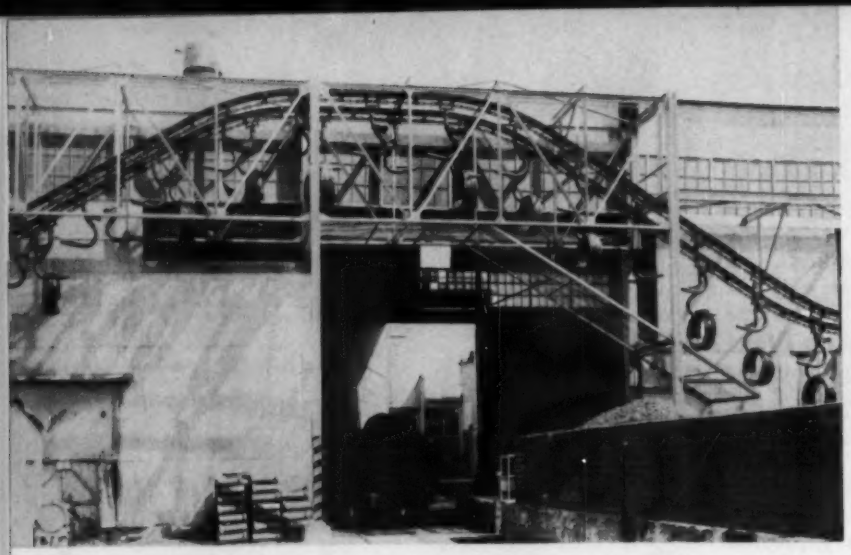


Fig. 8—Conveyor rises above railroad tracks on the way to storage building

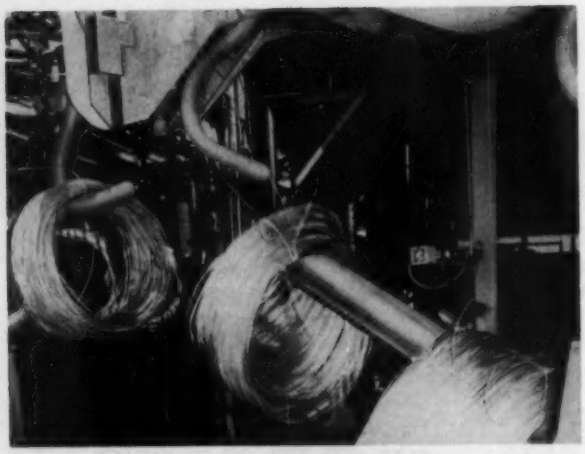
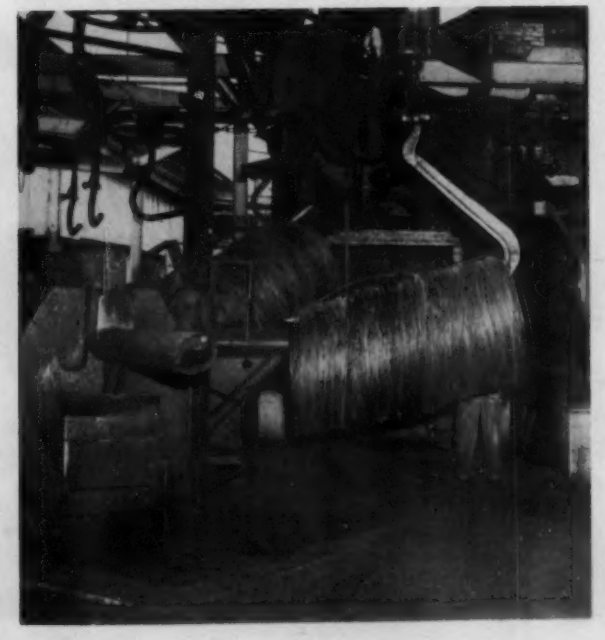


Fig. 9—Hooks are automatically tilted over raised arm of unloader in unloading operation. Unloader receives five coils then automatically indexes to present new arm in unload position

Fig. 10—Overhead crane is used to remove bundles of coils from unloading arm for transfer to final storage point



nected to two trolleys. Each hook is equipped with camming rollers near the curve of the hook which cause the hook to tilt at the drag conveyor transfer point, *Fig.* 6, and at the subsequent unloading station in the storage building. After receiving a coil, still insufficiently cooled, the 1400 foot long overhead conveyor moves through a circuitous path exposed to the atmosphere for complete cooling, *Fig.* 7. This part of the conveyor is raised well above ground level. Doubling back on itself after a 400 foot cooling run, conveyor directs the coils to the rod storage building located approximately 500 feet away from the original pick-up point. The flexibility of the chain type conveyor is illustrated by the change in elevation at one point to pass over railroad tracks on the way to the unloading station, *Fig.* 8.

The unloader is a large rotating unit which supports six horizontal projecting arms which are pinned and cam actuated to raise through a 25 degree vertical angle directly below a point at which hooks are tilted to discharge coils, *Fig.* 9. Each arm receives a preset number of bundles after which unloader indexes the next arm to the unload position. Final movement of the coils to a particular part of the building is by ram type tractor or crane hooks, *Fig.* 10.

▶ Design Features

As can be seen, in designing the entire conveying system, full advantage has been taken of the ability of coils to withstand relatively rough handling. The transfer and unloading mechanisms and the means of interlocking conveyor operations reflect an uncomplicated design so important to trouble free operation of a heavy duty system. Value of the conveyor to total operations has been increased by the concept of completely cooling the coils during movement to storage, even at the expense of increasing the length of the conveyor. Resulting system is a rugged adjunct to continuous coil forming operations, bringing rod production one step nearer complete automation.

GAGING OF PLATING THICKNESS

POINTS TO AUTOMATIC INSPECTION

Three new gages rapidly measure coating thicknesses nondestructively and provide suggestions for control of processes such as automated plating lines

FOR PROCESS CONTROL and inspection of the finished product in automated systems rapid, reliable procedures are required for measuring plating thickness of metallic coatings. While a great number of methods based on almost every metallic property have been developed for this purpose, few are nondestructive and direct-reading. Magnetic gages are widely used, but are limited to combinations in which at least one of the metals is ferromagnetic. Beta-ray and x-ray thickness gages are capable of fairly general application, but their high costs make them suitable only for large plants having considerable production volume. The beta-ray gage also has the disadvantage that its use is limited to large objects.

Demand for nondestructive test methods using economical instruments led to development at the National Bureau of Standards of three gages, each designed for a specific application in measuring the thickness of electrodeposited coatings. While all three instruments depend upon the difference in electrical conductivity between the coating and base metal, each makes use of a different method for sensing specimen resistance.

Although the three instruments were specifically designed for particular applications, the principles and units can readily be extended over a broad field of utilization. It is also obvious that the particular designs illustrated here can easily be altered for incorporation into semiautomatic and automatic equipment.

Inspecting Small Specimens

The Dermitron, *Fig.* 1, uses a very small single coil probe which must be placed against the specimen. Its small size makes it possible to measure plating thicknesses of small specimens and sharply curved surfaces.

The instrument makes use of the skin effect by which an eddy current induced in a metallic surface can be limited to a thin surface layer through the use of a high-frequency current as the inducing agent. The depth of penetration of the induced current is inversely proportional to the square root of the frequency of the inducing current and directly proportional to the resistivity of the metal. For a given frequency, the magnitude of the eddy current induced in a surface layer will depend upon the conductivity of the layer, other factors being constant. If the coating and the base metal have different conductivities, the effective conductivity of the composite surface layer, and hence the magnitude of the induced eddy current, will depend to a large extent upon the thickness of the coating.

In this instrument the magnitude of the induced eddy current is measured indirectly through the effect of its magnetic field which opposes that of the inducing current. Opposition of the two magnetic fields lowers the impedance of the high-frequency coil, thus permitting more current to pass through. The changes in the current flowing

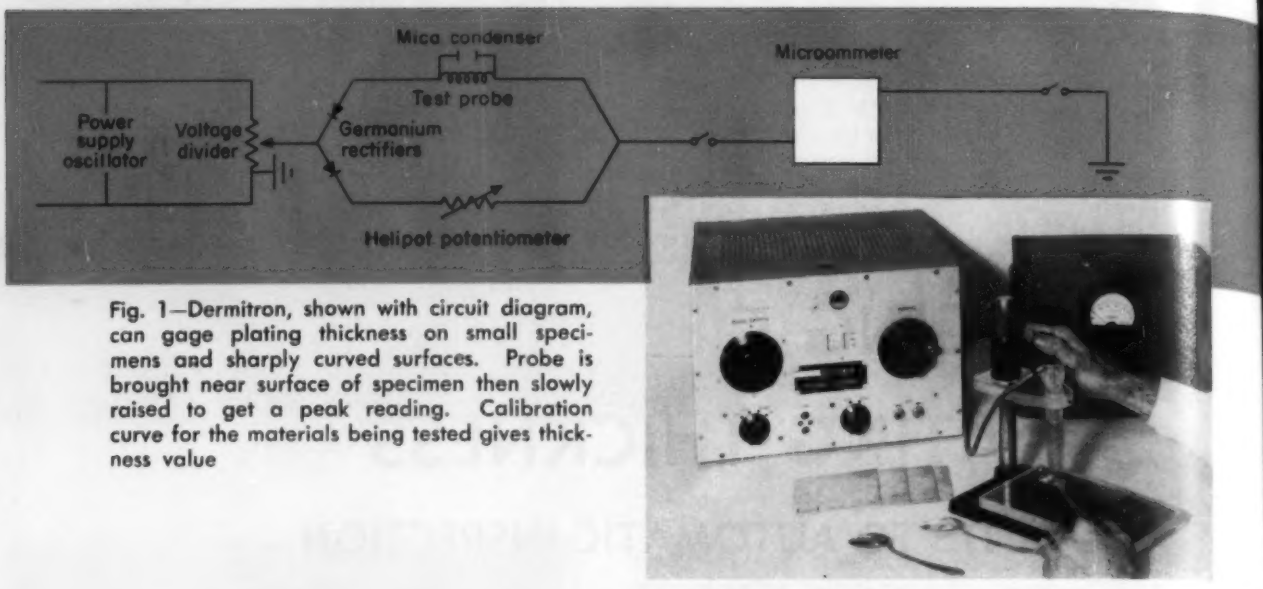


Fig. 1—Dermitron, shown with circuit diagram, can gage plating thickness on small specimens and sharply curved surfaces. Probe is brought near surface of specimen then slowly raised to get a peak reading. Calibration curve for the materials being tested gives thickness value

through the coil are shown on a meter in series with it.

In practice no calculations are required since calibration curves are used which are made with specimens of known thicknesses. Each pair of metals requires an individual calibration curve having two limits—one limit is the reading of the meter when the probe coil is brought near the bare base metal; the other is the reading with the probe adjacent to a layer of the coating that is thick enough to yield the maximum effect on the current.

Power is supplied by a commercial oscillator with a 6-watt output, and the amount of current through the circuit is controlled by means of a voltage divider placed across the oscillator. Between the voltage divider and a dc microammeter is a parallel circuit containing a variable resistance in one branch and in the other branch the probe coil with its capacitor. Each branch contains a germanium diode in opposite phase with the other. Thus, during one half of the cycle the current passes through the test probe and the meter, and during the other half of the cycle the current passes through the variable resistance and the meter in the opposite direction. The dc meter registers the difference between these two currents.

Range of thickness which can be measured by the Dermitron depends upon the frequency used. A given frequency may be used only for thicknesses through which a significant amount of current penetrates. High frequencies are most suitable for accurate measurement of thin coatings because the penetration of the current is shallower. At a frequency of 2 megacycles most coatings up to 1.5 mils in thickness can be measured accurately. A frequency of 100 kilocycles permits coatings up to 6 mils to be measured, but measurements of thin deposits are not as accurate at this frequency as at 2 megacycles.

The diameter of the test probe must be made small to diminish the effect of the geometry of the object on the measurement. This means that very low frequencies which require large coils, cannot be used to advantage. A typical coil, used at 2.5 megacycles is 0.030-inch in length and 0.10-inch in diameter.

Studies of the range and sensitivity of the gage at various frequencies and on different metal combinations are continuing. Another problem now under investigation is the possibility of making measurements of coating thickness without the use of prepared standards with which to calibrate the instrument. This might be done by using a range of frequencies rather than a single frequency, but practical difficulties must first be overcome.

▶ Gaging Plating on Large Areas

Originally developed for the rapid, continuous measurement of the thickness of silver plating on such large areas as stainless steel wave guides, the Phase-Angle Thickness Gage, *Fig.* 2, offers insensitivity to variation in probe-to-sample spacing on nonmagnetic materials.

The probe of this instrument consists of a mutual inductance transducer which is held in proximity to the sample. A buckout transformer, shielded from the influence of the sample, is also located on the probe head. These two elements are electrically connected and excited with radio-frequency current in opposition, producing output voltages whose phase difference is responsive to the conductance of the sample. A phase meter, specifically designed for use with the probe, is calibrated for the desired frequency ranges. The instrument is adjusted first for null phase difference when the probe is held away from the influence of the sample. Thereafter thickness readings are obtained by bringing the probe in proximity to the specimen—usually within ⅛-inch. The readings obtained are not affected by probe-to-sample spacing when it is less than this amount.

Operation of the Phase-Angle Thickness Gage is influenced by the characteristics of both the plating and the base metal, since both contribute to changes in the phase angle. As the resistivities approach the same value, it becomes difficult to differentiate between the plating and the base metal. If thickness of the base material varies, frequency of the exciter may be increased until the transducer field does not entirely penetrate the thinnest portion of the base. If the base thickness is constant, however, a higher sensitivity may be obtained by lowering the operating frequency to a point where the calculated skin depth of the material is greater than its thickness.

In a series of tests at the National Bureau of Standards, the instrument was used to measure the thickness of silver plated on one mil of nickel which was, in turn, plated on 37 mils of stainless steel. The results indicate that as the silver thickness increases, the phase angle approaches a value which might be obtained with silver alone. Experimental findings also show that nickel, with its high permeability, has an opposite effect to that of the silver plating in that it tends to reduce slightly the phase angle. The magnitude of the effect due to nickel is therefore a function of the silver thickness as well as of the quality of the nickel itself. Nickel quality is especially important if the nickel is of low grade and improperly applied, since its magnetic properties vary widely with impurity content.

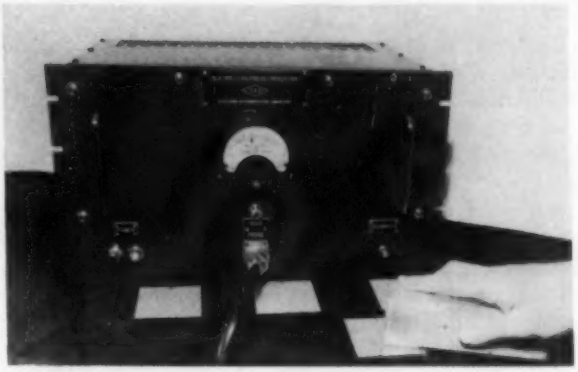


Fig. 2—Phase-angle Thickness Meter gages plating on nonmagnetic base metals with insensitivity to variations in probe-to-sample spacing. Meter in application shown indicates directly mils of silver applied to a base of 0.037-inch stainless steel

▶ Measuring Inside Plating From Outside

Designed specifically for measuring from the outside the quantity of silver plating on the inside of an L-band waveguide, the Plating Quantity Indicator, *Fig.* 3, is also useful for other plating or thickness measurements, and may be used on both nonmagnetic and magnetic materials without change of calibration.

Although the conductance measuring technique

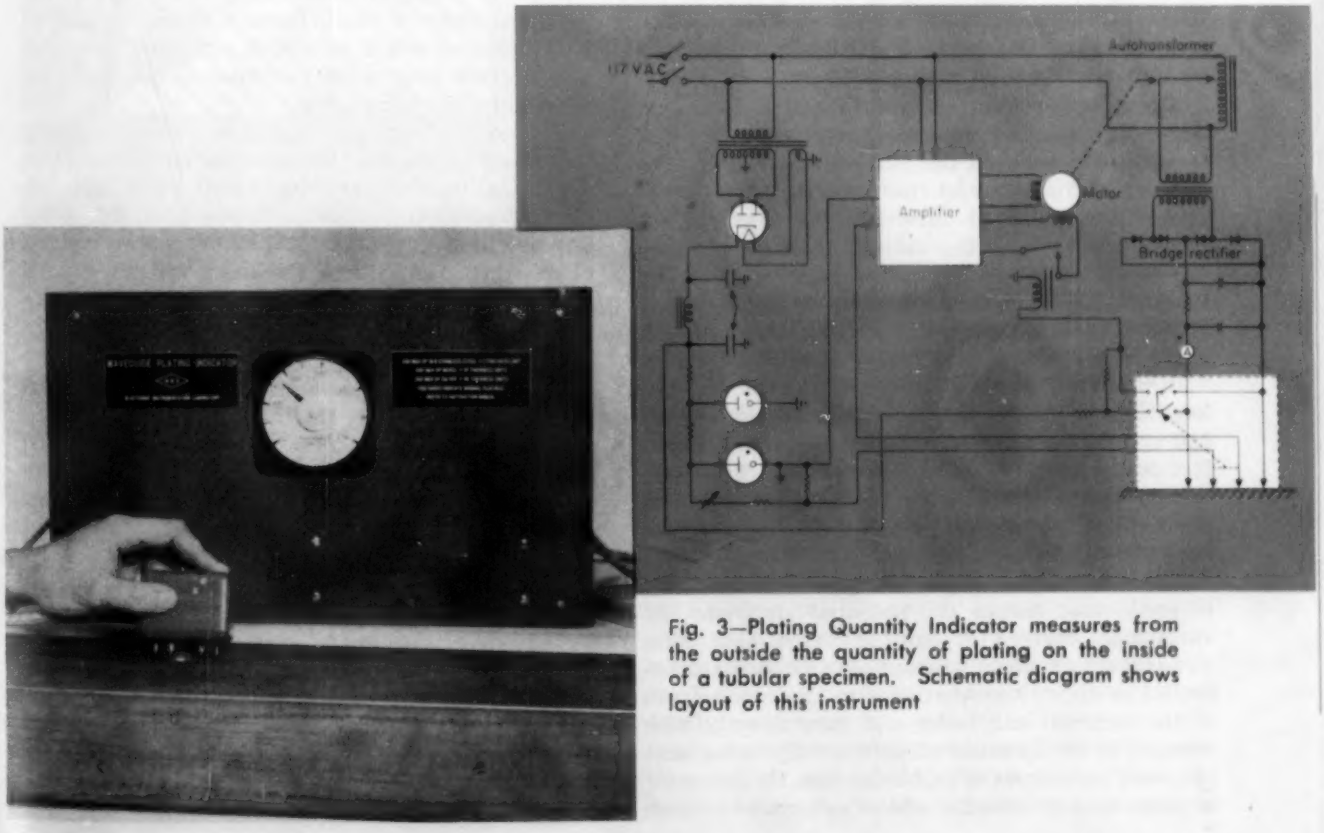


Fig. 3—Plating Quantity Indicator measures from the outside the quantity of plating on the inside of a tubular specimen. Schematic diagram shows layout of this instrument

has been used before to make thickness measurements of homogeneous plates, it is used in this application to determine the thickness of one material of high conductivity plated on another material of low conductivity. It actually measures the conductance of the silver deposited on the steel wall. Variations in the density and in the thickness of the silver cause a much greater change in the total conductance than similar variations in the steel. Local conductance is measured by passing a known amount of direct current through a portion of the specimen wall, using a pair of electrodes. By measuring the potential between two other points in the neighborhood of the current electrodes, the conductance can be determined, provided that the current flow is laminar throughout the material and that the linear dimensions of the material are several times greater than the electrode spacing. Laminar, or two-dimensional, flow is achieved by making the current electrode spacing much greater than the thickness of the specimen wall.

This Plating Quantity Indicator consists of two units. One is the probe which is applied to the specimen. The other is a chassis which contains the detecting and measuring circuitry, the power supply, and a calibrated indicating meter. The probe housing contains two pairs of electrodes to supply current and to measure potential. The two current electrodes provide a source and sink of current, and the two potential electrodes detect the potential between two points in the neighborhood of the current electrodes. The current electrodes are pointed brass rods spaced about two inches apart and are slightly blunted to keep the contact resistance low since they may pass up to five amperes. The potential electrodes are hard steel needles, spring-loaded, and projecting slightly beyond the current electrodes to ensure good contact.

The simplest electrode configuration is one in which the potential electrodes are aligned with and intermediate between the current electrodes. The position of the potential electrodes is chosen to obtain a high potential difference, but they are not placed too close to the current electrodes, where the potential gradient changes rapidly. Thus, reproducibility of readings is not affected by small changes in electrode point spacing which might occur as a result of handling and wear.

In use, the electrode points are aligned with the longitudinal axis of the specimen. Measurements can then be made even on corner bends with no effect on the accuracy of the instrument. Thickness measurements can also be made up to one inch from the end of the specimen before errors due to edge effect become important.

The circuit is designed so that a constant voltage is maintained across the potential electrodes by varying the current through the current electrodes. The current required to maintain the constant potential is directly proportional to the conductance of the material and hence will vary directly with changes in the quantity of plating. By using simple servo techniques of self-balancing, the indicator is made to read directly and is automatic to such an extent that the indicating meter and a power switch are the only components on the front panel. There are no operating adjustments.

When the probe is lifted from the specimen a switch in the probe housing shunts the current flow and at the same time disconnects the servo motor. Thus the ammeter reading is maintained whenever the probe is removed, and a rapid succession of readings can be made since the meter needle does not need to start from the zero mark for each reading.

In practice, an L-band waveguide usually has a layer of nickel plate between the silver and the steel to facilitate adhesion of the silver and to provide additional protection against corrosion. Studies of the relative conductances and thicknesses of the respective layers show that a direct measurement of the dc conductance between a pair of points will give sufficiently sensitive indications, within reasonable limits of error, of the amount of silver deposited on the nickel-plated stainless steel wall. This application of the instrument interprets this conductance measurement in terms of thickness units. One thickness unit is equivalent to the conductance of 0.001-inch thick stainless steel. Since nickel has a conductivity 10 times that of stainless steel, 0.001 inch of this material is equivalent to 10 thickness units. One-thousandth inch of silver, with a conductivity 48 times that of stainless steel, measures 48 thickness units. The specified composite of the three materials in the waveguide—0.037 inch of stainless steel, 0.001 inch of nickel, and 0.002 inch of silver—has a total relative conductance of 143 thickness units. If the amount of deposited nickel were to vary by 50 per cent, the error in the indication of the amount of silver present would be only 5 per cent. A variation of 0.005 inch in the thickness of the steel wall would have the same effect.

The conductivity of the plated silver may vary downward to one-half the nominal handbook value depending on the variables which enter into the electrodeposition process. However, if the metal is reasonably pure, the total error in this method of measuring equivalent thickness will not exceed five per cent. A limited series of controlled tests on plated samples showed a maximum error in thickness measurements of 1.5 per cent.

In addition to measuring the quantity of internal plating in a specimen, this instrument can be used to determine the thickness of homogeneous metal sheets, to sort metals, and to measure rapidly the conductivity of metallic sheets of known thickness. In the latter application, the conductivity can be computed by comparing the known thickness of the material with the instrument reading, or the instrument can be calibrated to read conductance directly for known thicknesses of material.

Each of these types of instruments has great possibilities for applications to which it may be suited. Further refinements and developments should prove of increasing value to industry since the trend to automatic production requires rapid gaging of products.

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Fig. 1—Rotary differential used in computing instruments for performing addition and subtraction. Input is to the large bevel gears; the pinion cage is keyed to the output shaft. If rotation is applied to one side-gear, rotation of the shaft is ½ the rotation of that side-gear. If rotations are applied to both side-gears, rotation of the shaft is ½ the algebraic sum of the two input rotations

COMPUTING MECHANISMS

INTEGRATE PROCESS CONTROL ELEMENTS

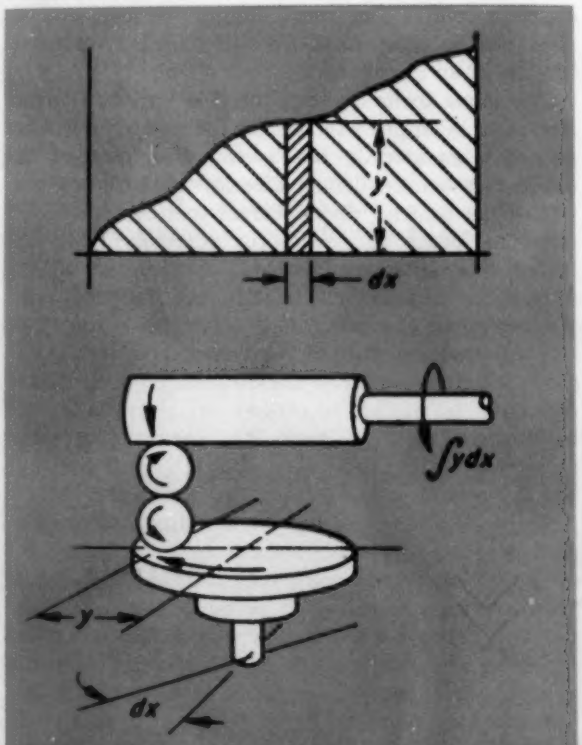


Fig. 2—Ball and disk integrator in which the disk is rotated by one of the inputs and rotation of the cylinder is the output. Positioning of the ball carriage controls the speed of rotation of the cylinder with respect to disk rotation and hence, this positioning is the other input

Direct control systems may become inadequate as industrial processes become more complex. Mechanical analog devices can perform complex operations to fill this need with relatively simple mechanisms and high reliability

CONTROL of industrial processes is dependent in many instances on variable quantities that are mathematical combinations of other variables measured more conveniently. These computing operations must be performed automatically if the trend toward automation is to be maintained.

Automatic computation may be performed in a number of ways. Available computing techniques fall into two major categories—analog and digital. Electronic digital computation is used for more complex operations, but for a large number of simpler operations, analog computation will prove more economical. In analog computation, the computer is a physical analogy of the mathematical relations which are to be solved to determine a desired physical quantity. An analog computer is usually composed of a number of computing elements, each representing some mathematical operation such as addition or multiplication. Such elements are appropriately interconnected to provide

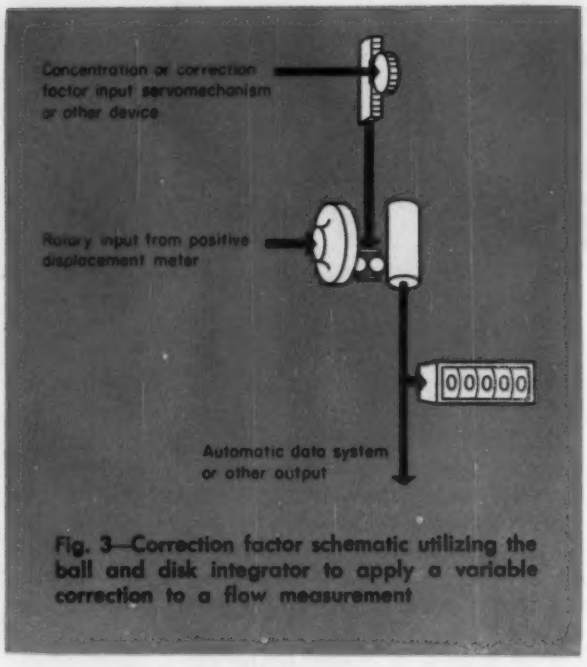

Concentration or correction factor input servomechanism or other device
Rotary input from positive displacement meter
00000
Automatic data system or other output

Fig. 3—Correction factor schematic utilizing the ball and disk integrator to apply a variable correction to a flow measurement

the solution to a particular problem. However, for certain problems, one computing device may simulate an entire problem.

Functions Performed

Mechanical analog computing elements have been developed to simulate most mathematical operations and important mathematical functions. These mechanical computing elements have physical displacements or rotations as inputs and outputs—linkages can be used for addition or subtraction when the inputs and outputs are displacements; when rotations are to be added or subtracted, a mechanical differential is used. A differential designed for use in computing instruments, *Fig.* 1, performs addition or subtraction. The rotary differential has the advantage over displacement-type additive or subtractive mechanisms in that there need be no physical limit to the total rotations of the inputs or outputs. Linear displacements must, of course, have practical limits in any real computer.

Multiplication is one of the more important mathematical operations and linkage multiplying mechanisms are available for mechanical analog multiplication. The inputs and the output of such mechanisms are displacements rather than rotations. By the very nature of the problem, inputs and output of a multiplier are limited to practical finite values. Racks and pinions can be used to convert quantities available as rotations into displacements. By the same means, displacements can be converted to rotations. If multiple revolutions of a shaft are required, it may be necessary to use some means of power amplification, such as a servomechanism.

There also are computing elements which perform operations such as the generation of trigonometric and square functions. A particularly useful mechanical computing element is the mechanical integrator, *Fig.* 2, which is essentially a precision variable speed drive. The ball carriage carries a sleeve in which two precision steel balls fit freely, but with a minimum of clearance. A spring in the disk bearing assembly urges the disk toward the cylinder. The disk and the cylinder are separated by the two balls. The force exerted by the disk spring provides the traction necessary to transmit the rotation of the disk, through the balls, to the cylinder. The speed of rotation of the cylinder is proportional to the distance between the balls and the center of the disk.

Computing Applications

Application of these computing elements can be understood best through examples. Consider a case in which the requirement is to continuously multiply a rate of flow by some variable quantity and to indicate the result, or integral, over a period of time. There are several different applications which employ essentially the same type of computation. A varying fluid flow may be measured by a positive displacement meter; this fluid might contain a component of measurable and variable concentration. The total amount of this component can be determined over any time interval by the use of an integrator.

The same technique applies if a variable correction is to be applied to the flow, such as the system shown schematically in *Fig.* 3. The disk of the integrator can be driven directly with rotary output of the positive displacement meter. If it is desired to locate the computer remotely from the meter, a synchro transmission system can be employed to transmit electrically the rotation from the meter to the computer. The ball carriage of the integrator would be positioned proportional to the concentration or other factor. If this factor is available as an electrical quantity, a servomechanism, as used in self-balancing potentiometers, would be used to position the ball carriage or, if available as a 3 to 15 psi pressure, then a bellows and spring arrangement can be used to position the ball carriage. Rotation of the integrator cylinder is a continuous totalization, or integration, of the product of flow and the multiplying factor. When both the flow and factor are variables, use of an integrator is a more accurate method than multiplying a total flow by an average factor.

Instead of determining the amount of a component of variable concentration in a fluid flow, it might be desirable to totalize the weight on a conveyor belt to determine the amount of material carried by the conveyor between any two readings of an output counter. In this case, the disk of the integrator would be rotated from a conveyor roller, either by direct coupling or by

synchros as in the case of the positive displacement meter. A fixed length of conveyor would be weighed by some type of scale capable of remote transmission. If the weighing is done by strain gage load cells, a servomechanism would be used to position the integrator ball carriage as before. If a pneumatic load cell is used, then a bellows and spring arrangement could be used to position the ball carriage.

Outputs of several integrators can be totalized using mechanical differentials. Thus, the total flow or weight can be indicated for several flow-meters or conveyors. By means of an automatic data processing system, the results can be printed automatically for a number of process lines. Information can also be recorded in punched paper tape or punched cards for the compilation of accounting information by computing equipment or could be introduced directly into an electronic digital computer for the compiling of accounting information, the automatic control of blending, and other process operations for optimum operation of the plant.

Complex Systems

Although the integrator systems described are relatively simple, identical principles can be extended to more complicated problems. An integrating computer, *Fig.* 4, used in color analysis to compute the three stimulus values which define a color, is operated with the General Electric recording spectrophotometer. One input, the wavelength, λ, is slowly changed during a test. The other input is the measured reflectance at corresponding wavelengths. The two inputs are received by synchros used in servomechanisms which provide more power and accuracy than would be available from torque transmitting synchros alone. The three outputs from the computer are three stimulus values which are displayed on mechanical counters.

Another application which may be of interest is the use of an integrator as a speed ratio computer, *Fig.* 5, when it is desired to determine the ratio of speeds between two positive displacement flowmeters or two shafts or rolls in some machine. The two shaft rotations are introduced either as shaft inputs or as synchro inputs and the first input drives the integrator disk. The cylinder of this integrator drives one side-gear of the mechanical differential through gearing; the other side of the differential is driven by the second input. When the two side gears of the differential are rotating at the same speed, there will be no rotation of the output of the mechanical differential. The ratio of the integrator cylinder speed to the integrator disk speed is proportional to the ball carriage displacement from zero. Therefore, when there is no output from the differential, the ball carriage displacement of the integrator will be a

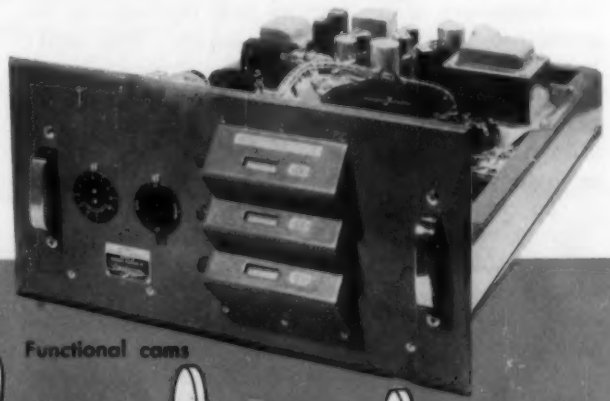
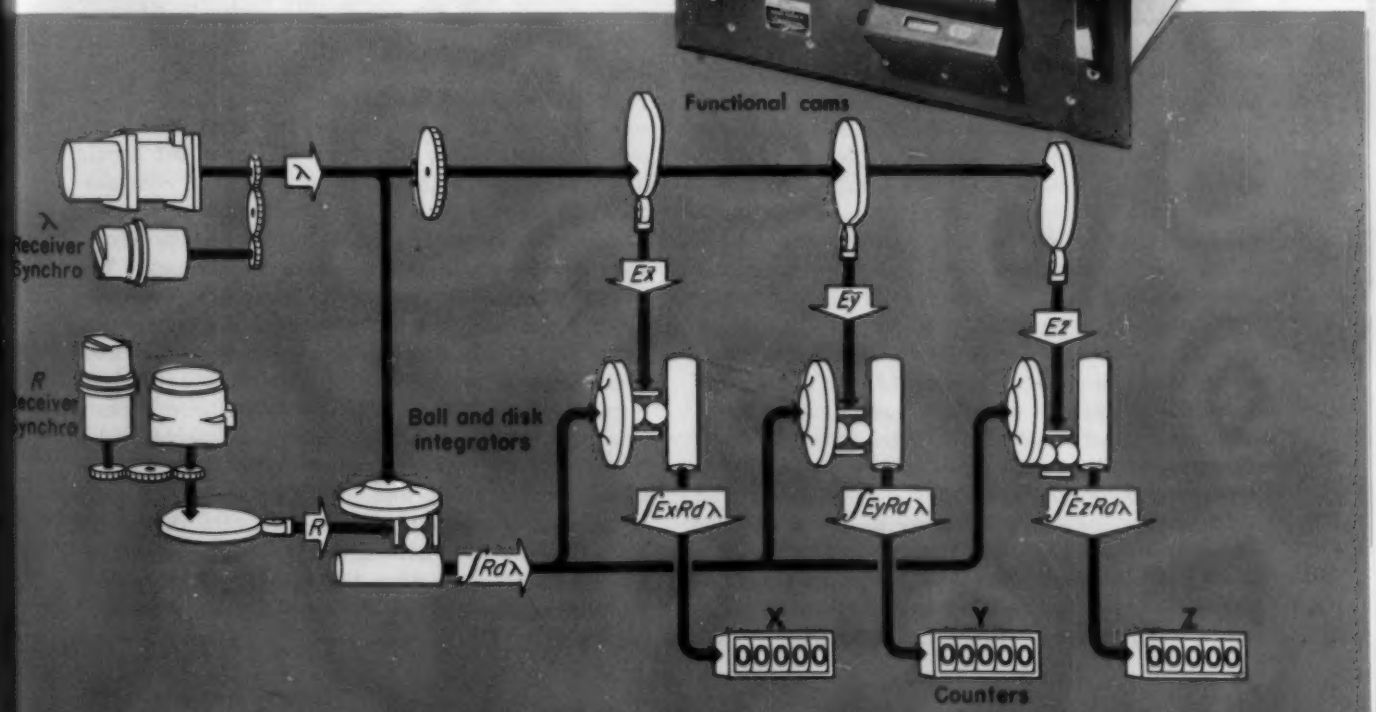


Fig. 4—Integrator system used to compute tristimulus values which define a color. Inputs are wavelength, λ, and reflectance, *R*, and it can be seen from the schematic that double integration is performed to arrive at the computed output values



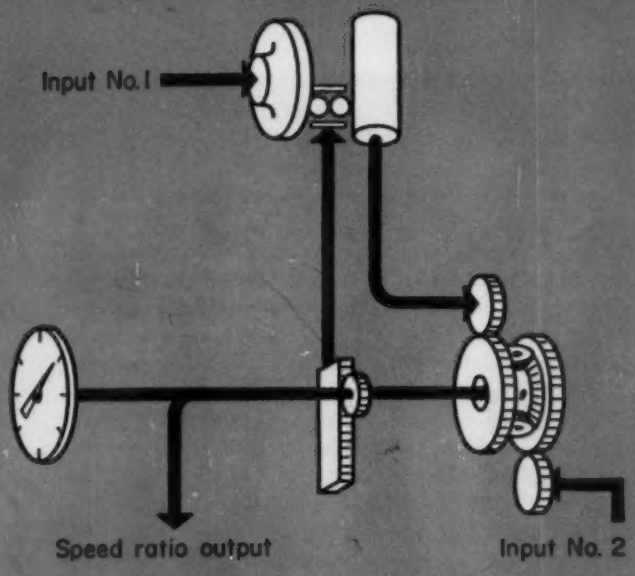


Fig. 5—Schematic of a speed ratio computer in which the differential output feeds back a displacement to the ball carriage in a direction which tends to stabilize the differential output and makes the position of the ball carriage a function of speed ratio of the two inputs

measure of the ratio between the second input to the differential and the integrator disk speed. In order to make this ratio computation automatic, provisions are made for the ball carriage to be positioned by the differential output. This feedback loop between the differential and the ball carriage must be so connected that a difference in the speeds of the two differential side gears causes a differential output which moves the ball carriage in the direction which will tend to make the speeds of the two differential side gears equal.

After any change in the speed of one of the inputs to this system, the ball carriage will move toward the position corresponding to the new ratio. In this system, the speed at which the ball carriage moves toward the correct solution after a disturbance is proportional to the distance that the ball carriage is from the correct solution position. This means that movement of the ball carriage after a sudden change in speed of one of the inputs is an exponential function with respect to time. The time constant associated with this computation acts to smooth variations in the ball carriage position due to variations in the inputs. The solution time in this type of system depends on the integrator disk speed and the gear ratio from the integrator cylinder, through the differential, and back to the ball carriage. The solution time can be held to less than a second if the disk speed is 100 rpm or greater.

These few examples are indications of the capabilities of mechanical analog computing elements. In general, almost any equation can be mechanized with mechanical analog computing elements. Empirical functions are also readily generated by cams or other devices. Some problems require use of electromechanical or pneumatic servomechanisms in the solution. The accuracy of individual computing elements such as the mechanical integrator is approximately 0.1 per cent. The accuracy of even very complex computers can be held to less than one per cent of full range.

Considerations for Choosing a System

When the automation engineer finds that the use of some form of computation is indicated in his equipment, he must then decide upon the means most suitable for the application. The decision will be influenced by the following factors:

1. Complexity of the computation.
2. Character of the inputs and the outputs—whether they are electrical, mechanical, pressure, or force, and what scale factors can be used.
3. Accuracy required.
4. Required speed of response of the system.
5. Power available.
6. Environmental conditions.

For certain combinations of characteristics, one type of computation may prove considerably more advantageous than others. For example, if a shaft rotation is required to be multipled by a variable quantity available as a mechanical displacement, a mechanical integrator is indicated. On the other hand, an extremely complex computation which requires very small errors but does not require continuous outputs, can be handled best by electronic digital techniques.

Use of mechanical analog computation is indicated in various situations. Analog computation, in general, is indicated where the computational problem is not complex enough, or the accuracy requirements are not severe enough to justify economically the use of an electronic digital computer. Use of mechanical analog computation is especially indicated where mechanical inputs are available in a suitable form, and where the mechanical outputs can be readily utilized. Manually set inputs are compatible with mechanical analog computation. Ruggedness, reliability, and ease of maintenance of mechanical devices often influence their selection in preference to other techniques. The use of mechanical computing devices is also indicated where there is a hazard of fire or explosion. Often the inputs provide the only power required.

Continuing developments in all types of computing techniques are making computations practical which could not be economically performed a few years ago. The increased complexities, faster speeds of operation, and increased operating costs of modern industrial processes require that more computations be performed. It is inevitable that all classes of computing techniques will see much greater application in industry within the near future.

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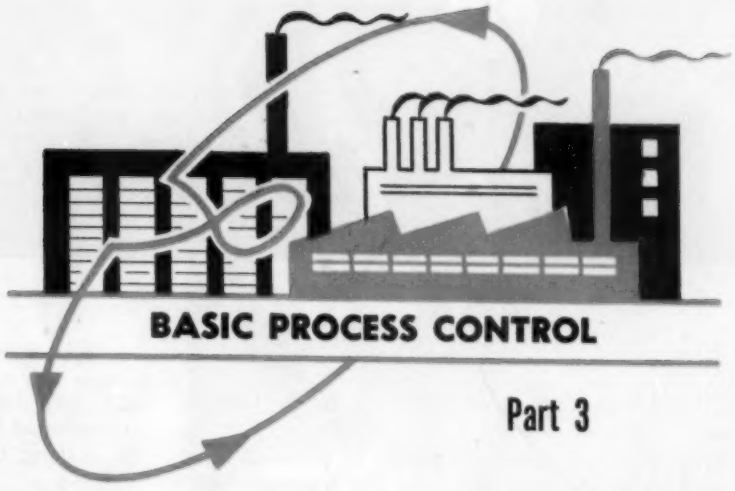

CONTROL SYSTEM DESIGN

Combining of components into a system which will control a variable to desired specifications requires an understanding of the system approach. This use of frequency-response techniques allows consideration of component characteristics and provides a convenient method to analyze system response

AN AUTOMATIC control system is made up of a number of components, as previously emphasized in the first article of this series. Attention was later called to the fact that although it is convenient to examine the various components separately, the system must finally be considered as a whole. Since all control system components are essentially energy storage or transfer devices, they possess dynamic characteristics which must be recognized in the design of the control system.

Essentials of a basic automatic control system are:

1. Controlled variable, or a measurable quantity related to the desired properties of the process product.
2. Measuring element, or a device for measuring the value of the controlled variable.
3. Final control element, or apparatus capable of effecting a change in the controlled variable.
4. Controller, or means for operating the final control element in response to signals from the measuring element.

Fundamental feature of a basic process control system is the dependency of the controlled variable regulation on the measurement. It will be seen that by linking the final control element to the measuring element, the controller brings a closed-loop system into being; hence the term closed-loop automatic control system.

Although the controlling unit operates the process, it can also be seen that it is the process which actuates the controlling unit. Therefore, performance of any controlling instrument is dependent on the particular system of which it is a part. The basic problem of automatic control design is a system problem where every component of the system is considered in the design.

Block Diagram Aids

Control systems rarely are comprised of components of only one kind. Frequently combinations of mechanical, electric, electronic, hydraulic, pneumatic, thermal, and many other physical devices are combined into a single system. Diagrams or engineering drawings of these systems are frequently too cluttered with detail to be usable for system analysis. The equivalent circuit or schematic diagram may also contain so much detail that

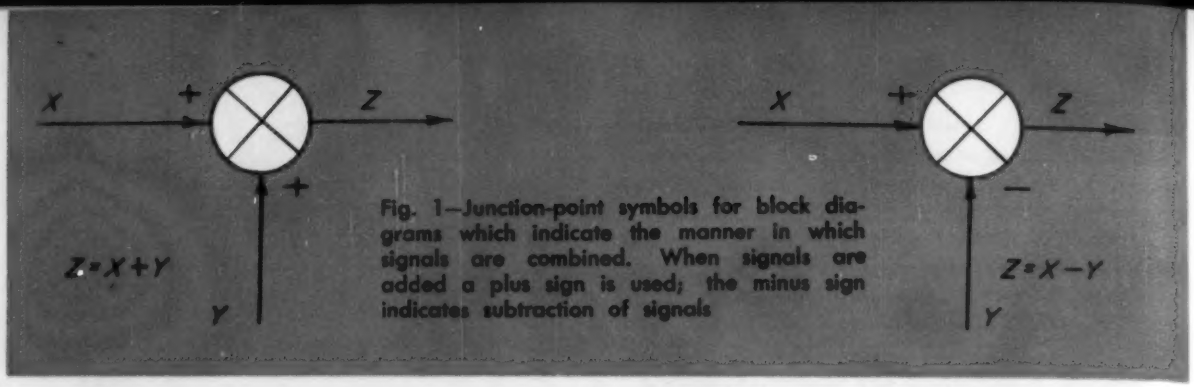

Fig. 1—Junction-point symbols for block diagrams which indicate the manner in which signals are combined. When signals are added a plus sign is used; the minus sign indicates subtraction of signals

to make reference to it involves much tedious work.

Because of the basic similarity of physical laws governing energy transfer, once the transfer function of a system or component has been derived, the physical nature of the device is of no importance in the mathematical analysis. Hence, simplifications can be made in representing components and their transfer functions. Instead of complicated schematic drawings, an equivalent block diagram can be drawn.

A block diagram is a functional layout of an entire system in which the transfer functions of components are shown in blocks and the flow of signals is shown by lines connecting the blocks. Each of the blocks represents a property required for the function of the control system, and is an independent unit in that the connections between blocks do not effect the transfer functions.

In setting up the block diagram of a system, the engineer is confronted with something of a choice in locating boundaries of the blocks. Points in the system where a conversion of energy takes place are usually good choices for component boundaries. For any choice, caution should be exercised so that the chosen limits of the block represent an actual isolated component of the system. In normal practice, the characteristics of the component are represented by the transfer function obtained either by testing or from a theoretical analysis of the component.

Block diagrams consist of arrows showing the direction of signal flow, differential and summing symbols which indicate the manner in which signals are combined, *Fig.* 1, and boxes. The various stages in the construction of the block diagram of a simple pressure process are shown in *Fig.* 2. In the procedure of arriving at a suitable block diagram as many mechanical and electrical details are omitted as possible. An amplifier which serves only to increase the signal size may be designated simply by the gain K, leaving the actual tube type, power supply levels, etc., to the electrical schematic. However, if the amplifier contains a filter to eliminate high frequencies, the filter characteristics should be included.

Since the object of a block diagram is to present as much information as possible in compact form, the transfer relation associated with each box should combine brevity and clarity in such a manner that the nature of the relation is immediately evident. It naturally follows that preparation of the block diagram often can be made too difficult by inclusion of many unnecessary compo-

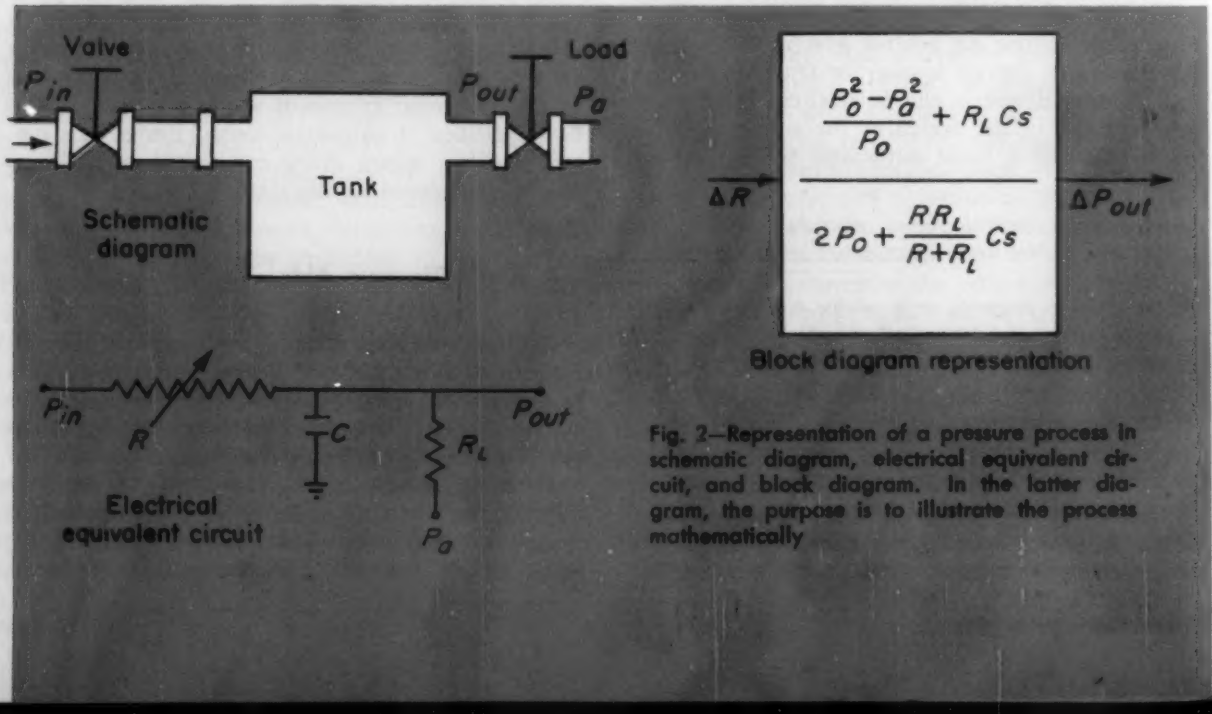

Fig. 2—Representation of a pressure process in schematic diagram, electrical equivalent circuit, and block diagram. In the latter diagram, the purpose is to illustrate the process mathematically

nents. On the other hand, no element can be ignored in the system block diagram whose response contributes measurably to the overall system response. Block diagrams can be extremely useful in the analysis of automatic control systems, since any complicated system can be represented by a series and parallel arrangement of blocks and shown on a simple line diagram.

The System Problem

End result of a system analysis is to arrive at a control system design which will yield the desired response of the controlled variable. It has already been shown that an automatic control system is a combination of several components whose functions act in harmony to produce a desired result. Although it is relatively simple to analyze each of these components individually, the problem of analyzing performance of the entire system, *Fig.* 3, and determining which component may be responsible for unsatisfactory control can be very difficult.

If the four components of *Fig.* 3 are connected in series as shown, the output of the controller becomes the input of the valve, while the output of the valve becomes the input of the process, and the output of the process becomes the input of the measuring element. It was shown in the second article of this series that if each component is subjected to a step-type disturbance, the resulting output, because of its inherent energy storage characteristics, will be of a form other than a step response.

It is evident that for a step disturbance to the controller input, the valve, process, and measuring element receive inputs that are not of the step type, and it becomes difficult to obtain the response of these components for the mathematically complicated inputs they receive as components of the series system. Thus, the response of the measuring element, which is the response of the series arrangement, is difficult to obtain analytically.

Therefore, the implication is that an input signal should be chosen which causes a system output of the same form as the input. Such a choice can be seen to allow the use of the transfer function concept, since every component will receive the same form of input when connected as a system. This criterion of analysis is satisfied by a sinusoidal input, and it is one of the principal reasons for choice of a sine wave input. Another justification for use of the sine wave signal is that integration and differentation of such a signal will give a wave of the same form. This is of great utility in the study of dynamics, since it is often necessary to deal with derivatives and integrals of the input.

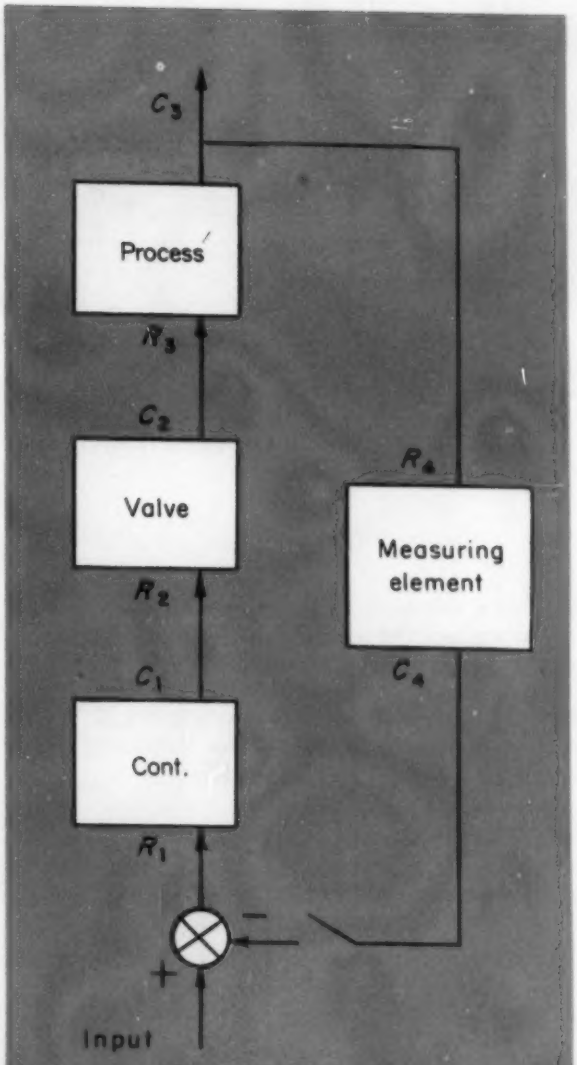

Fig. 3—System composed of a controller, valve, process, and measuring element. The feedback path has been broken between the measuring element and the controller resulting in an open-loop system. The combined characteristics of the four components traced in an unbroken series path are known as the open-loop characteristics of the control system

System Frequency Response

If the driving force or input to a linear system is of sinusoidal form, the response will also be sinusoidal during steady state. This will be shown to be true by solving for the response of a linear sys-

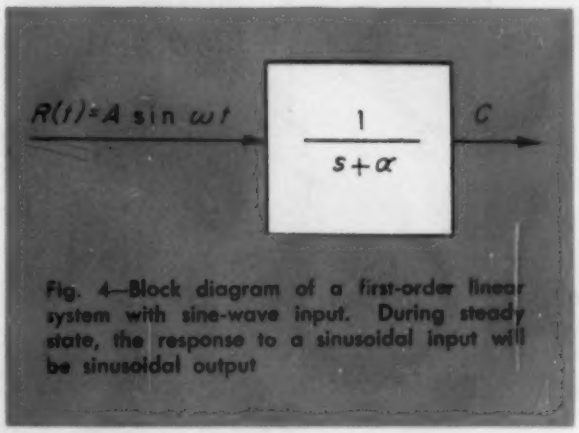

Fig. 4—Block diagram of a first-order linear system with sine-wave input. During steady state, the response to a sinusoidal input will be sinusoidal output

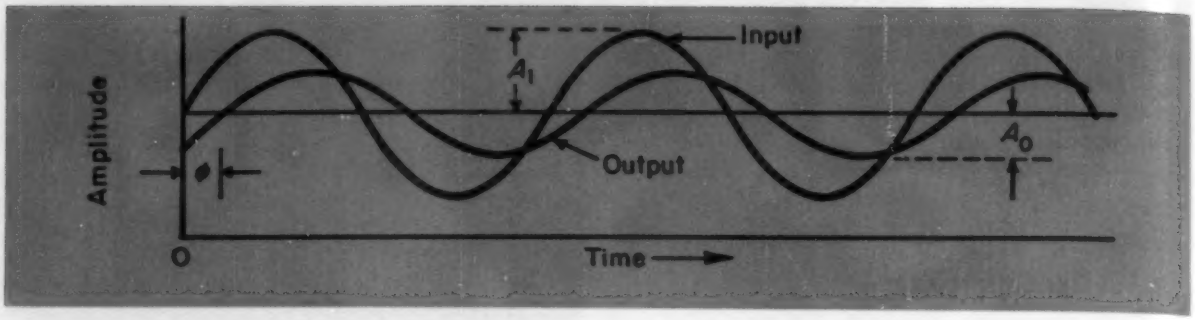

Fig. 5—Plot of input and output sine-wave signals as a function of time. This output signal has an amplitude less than the amplitude of the input signal and is said to be attenuated. Had the output amplitude been larger, it would possess gain

tem for a sine wave forcing function. The LaPlace transform method discussed in Part 2 of this series will be used in establishing this proof.

Assume that the system can be described by the first-order transfer function shown in *Fig.* 4. From a table of transforms the LaPlace transform of the sine wave input $A \sin \omega t$ is found to be

$$\frac{A\omega}{s^2 + \omega^2}$$

The transfer function of the component is

$$\frac{C}{R}(s) = \frac{1}{s + \alpha} \quad \ldots\ldots (1)$$

Therefore,

$$C(s) = \frac{A\omega}{s^2 + \omega^2} \times \frac{1}{s + \alpha} \quad \ldots\ldots (2)$$

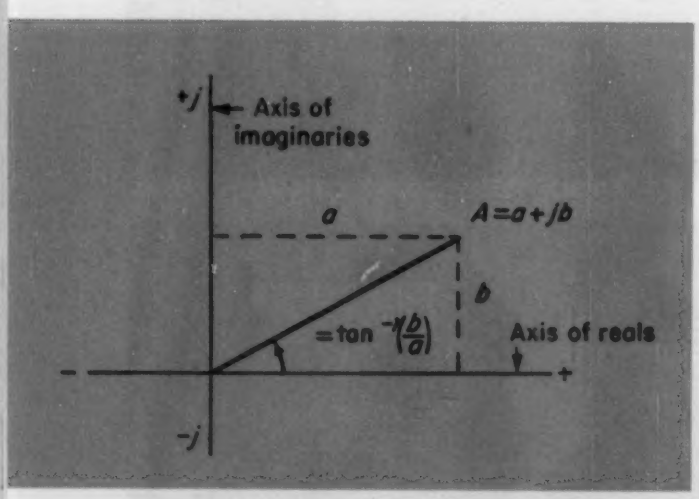

Fig. 6—The complex plane in which an imaginary number can be represented by a point located on an axis at right angles to the axis of real numbers. Positive rotation has been taken to be counterclockwise and $\sqrt{-1}$ has been indicated by the symbol j

Using partial fractions this can be expressed as

$$C(s) = \frac{A\omega}{\omega^2 + \alpha^2}\left(\frac{1}{s + \alpha} - \frac{s - \alpha}{s^2 + \omega^2}\right) \quad \ldots\ldots (3)$$

Since only the steady-state response is of interest, the transient term $1/(s + \alpha)$ will be neglected. Therefore, the steady-state solution becomes

$$C(s)_{ss} = \frac{-\omega A}{\omega^2 + \alpha^2}\left(\frac{s - \alpha}{s^2 + \omega^2}\right) \quad \ldots\ldots (4)$$

From inverse transform tables the time solution becomes

$$C(t)_{ss} = \frac{A}{\sqrt{\omega^2 + \alpha^2}} \times \sin(\omega t - \phi) \quad \ldots\ldots (5)$$

where

$$\phi = \tan^{-1}\left(\frac{\omega}{\alpha}\right)$$

Thus the output response of the linear system is in the form of a sinusoid at the same frequency as the input, but with a phase lag of ϕ and an amplitude of $A/\sqrt{\omega^2 + \alpha^2}$. Input and output to this component have been plotted in *Fig.* 5 as a function of time. The phase shown is called a phase lag, since a point on the output wave lags in time a corresponding point on the input wave. This time lag is expressed in degrees by multiplying the ratio of the lag time to the period of the input wave by the 360 degrees traced in a complete cycle. A phase lead merely signifies that the output leads the input by a finite number of degrees.

▶ Vectors and Complex Numbers

The characteristic of having an amplitude and phase relationship suggests the use of vector notation in expressing these input-output relationships. Vector notations and manipulations are based upon the theory of complex numbers. While a complete treatment of this theory is beyond the scope of this discussion, it is of interest to review briefly the philosophy of complex numbers and vector notations.

All real numbers, whether positive or negative, integral, fractional, or irrational (as $\sqrt{2}$) can be represented by points on a line indicated as the

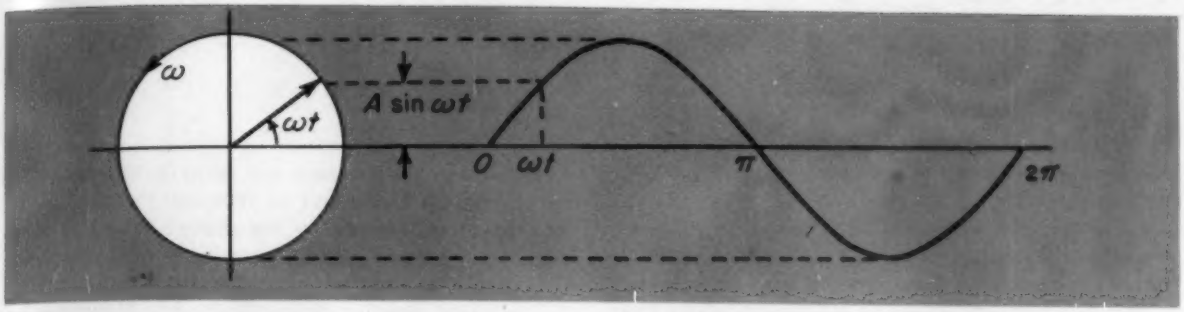

Fig. 7—Sine wave as a projection of a rotating vector. Radius of the circle generated is A and the vector is rotating at a constant angular velocity of ω radians per unit of time

axis of real numbers on a complex plane as shown in *Fig.* 6. The concept of adding and subtracting real numbers by the addition of directed line segments (plane vectors) along the real axis is familiar in mathematics. Furthermore, the results of adding, subtracting, multiplying, or dividing real numbers are always other real numbers which also can be represented by points on this axis. However, there is no place on this axis for the square roots of negative numbers which frequently arise in dynamic analysis for there is no real number whose square is negative. This has given rise to the name "imaginary" for such numbers.

It can be seen from the complex plane that multiplication of either a positive or a negative number by -1 can be regarded as a 180-degree rotation of the point representing this number about the origin. Since this amounts algebraically to two multiplications by $\sqrt{-1}$, it is expected that multiplication by $\sqrt{-1}$ is represented by a rotation of the point through 90 degrees. Any imaginary number can be expressed as $\sqrt{-1}$ times a real number, for example $\sqrt{-9} = 3\sqrt{-1}$.

Having visualized real and imaginary numbers as points on two mutually perpendicular axes, or as plane vectors joining the origin and these points, the next step is to represent the sum of a real and an imaginary number. This is the so-called "complex number", and is of the form $a + jb$ where a and b are real numbers and j is $\sqrt{-1}$. This addition will be found to follow the law for addition of plane vectors, and could be represented by a point with coordinates a and jb or by the associated vector A on the complex plane as illustrated in *Fig.* 6.

The length or absolute value of the vector A can be represented by A, and the angle it makes with the positive real axis by ϕ. Mathematically this can be expressed as

$$\overline{A} = a + jb \quad \ldots\ldots (6)$$

So

$$A = |\overline{A}| = \sqrt{a^2 + b^2} \quad \ldots\ldots (7)$$

and

$$\phi = \tan^{-1}\left(\frac{b}{a}\right) \quad \ldots\ldots (8)$$

It is evident from a geometric consideration that the complex number A can be expressed in terms of its absolute value and angle by

$$\overline{A} = A\ (\cos\phi + j \sin\phi) \quad \ldots\ldots (9)$$

Euler's formula states that

$$e^{j\phi} = \cos\phi + j \sin\phi \quad \ldots\ldots (10)$$

Comparison of this expression with Equation 9 indicates that the quantity $e^{j\phi}$ can be represented by a plane vector having an absolute value of unity and located at an angle counterclockwise from the real axis. Furthermore, by substituting Equation 10 in Equation 9 the complex number A can be expressed in compact exponential form

$$\overline{A} = Ae^{j\phi} \quad \ldots\ldots (11)$$

This can also be written in polar form as

$$\overline{A} = A \angle \phi \quad \ldots\ldots (12)$$

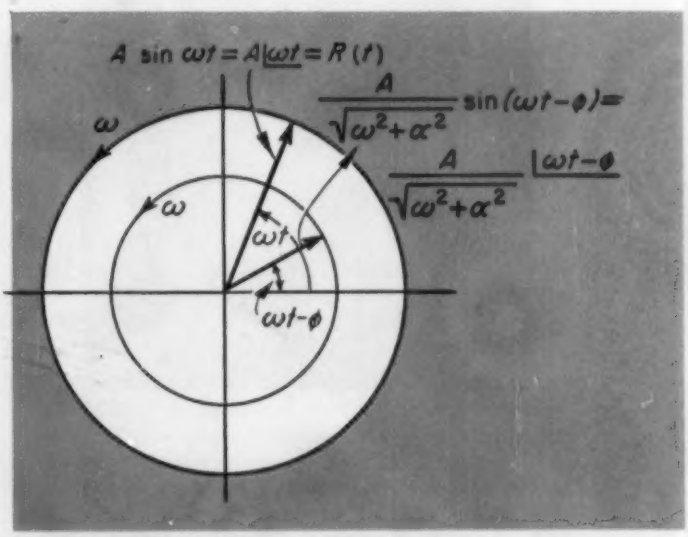

Fig. 8—Vector notation of sinusoidal input and output of a linear system. There is a phase lag of ϕ between the input and output

The fundamentally correct unit for ϕ is the radian, although degrees are almost always used for convenience.

A method for obtaining the frequency characteristics of a linear system will be illustrated, using complex numbers and vector notation. As shown in *Fig.* 7, a sine wave can be expressed as the projection of a rotating vector on a fixed axis. This vector has a length A and is rotating at a constant angular velocity ω radians per unit of time. The angle of this vector with respect to the horizontal axis is ωt, and the projected length of this vector on the vertical axis is $A \sin \omega t$. In vector notation this is expressed as

$$A \sin \omega t = A \angle \omega t \qquad (13)$$

Consider now the use of vectors as shown in *Fig.* 8 to represent the sinusoidally varying input and output signals of the linear system just analyzed. Using this convenient notation, the ratio of output to input can be formed as follows:

$$\frac{C}{R}(j\omega) = \frac{\dfrac{A}{\sqrt{\omega^2 + \alpha^2}} \angle \omega t - \phi}{A \angle \omega t} \qquad (14)$$

Equation 14 represents a division of two complex quantities. The absolute value of the quotient can be obtained simply by dividing the two magnitudes while the angle associated with the quotient is the difference in the two angles. Thus the ratio becomes

$$\frac{C}{R}(j\omega) = \frac{1}{\sqrt{\omega^2 + \alpha^2}} \angle -\phi \qquad (15)$$

Equation 15 expresses the ratio of the output to the input as a function of frequency ω and is the same ratio expressed by the system transfer function. In fact, it can be shown that the transfer function expressed as a function of frequency will be the same complex ratio obtained in Equation 15. For instance, consider the linear first-order component previously analyzed whose transfer function was defined by Equation 1. Substituting $j\omega$ for s in Equation 1 yields

$$\frac{C}{R}(j\omega) = \frac{1}{\alpha + j\omega} \qquad (16)$$

where $\alpha = 1/$ (time constant) or $1/\tau$.

This equation is the transfer function in complex form and can be expressed as a vector as follows:

$$\frac{C}{R}(j\omega) = \frac{1}{\sqrt{\omega^2 + \alpha^2}} \angle -\phi \qquad (17)$$

where

$$\phi = \tan^{-1}\left(\frac{\omega}{\alpha}\right)$$

Equation 17 is identical to Equation 15. It is important to realize the significance of the identity of these two equations. This identity shows that the transfer function of a linear device or system may be obtained by a mathematical analysis or from an actual test using sine wave inputs. This test would consist of applying a sine wave input to the actual system and measuring the relative amplitude and phase shift caused by the system at the output.

Such tests on an actual production process have already been successfully conducted and reported upon.[1,2] A theoretical analysis made on a system could be correlated with test data obtained from the actual system. Even more important is the fact that if a complicated process or device cannot readily be analyzed mathematically, its transfer function may be obtained by test and then combined with the transfer functions of other components, whether obtained by test or calculation, to yield the response of the entire system.

In the preceding discussion, the sinusoidal driving functions considered have been of a single frequency. If, in the analysis of a system, calculations are made for only one frequency, the knowledge of the system performance will be limited to that frequency. In certain cases this information may be sufficient but, in general, one is almost always interested in knowing the response of the system for a range of frequencies.

If numerical values of $(C/R)(j\omega)$ are computed or measured for a specific system and for a number of sinusoidal input frequencies, the result will be a series of vectors. The magnitude of each vec-

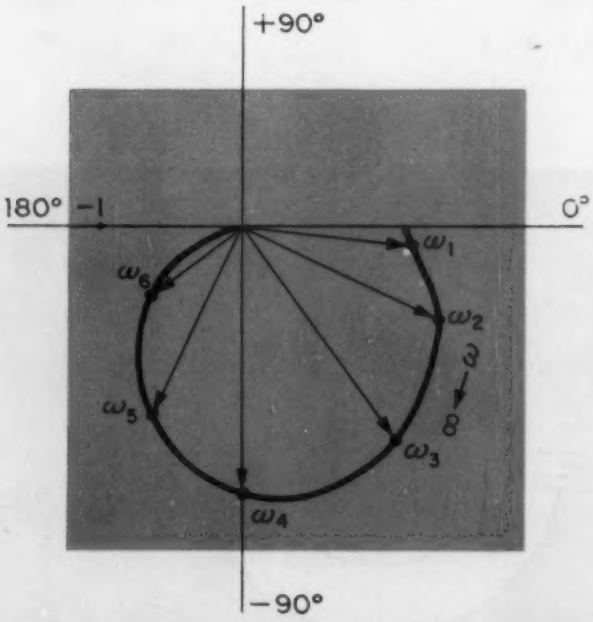

Fig. 9—Polar plot of frequency response of a second-order system ($\xi = 0.3$) also known as a Nyquist diagram. A family of curves is realized for different values of damping. Principle advantage in the use of a polar plot is that it expresses all of the frequency characteristics in a single curve

[1] References are tabulated at end of article.

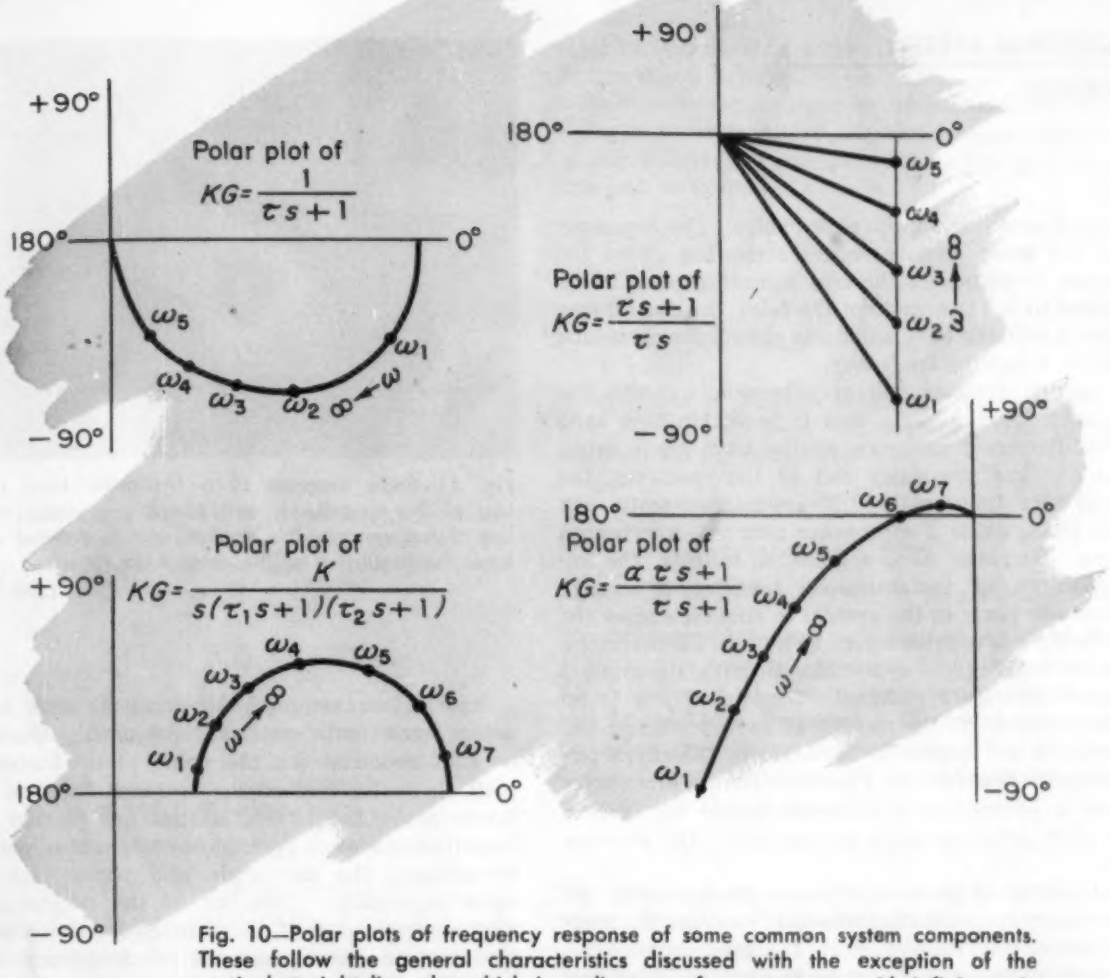

Fig. 10—Polar plots of frequency response of some common system components. These follow the general characteristics discussed with the exception of the vertical straight line plot which is a diagram of a component with infinite gain and a phase shift of −90 degrees at zero frequency. This is the frequency response of a theoretical proportional-plus reset controller which has a characteristic of infinite gain at steady state to prevent controlled variable offset

tor is the magnitude of the ratio C/R and the phase angle of the vector is the angle between C and R. The frequency characteristics of the device or system thus obtained are called, by definition, the frequency response of the device or system.

▶ Polar Plots of Frequency Response

Polar plot of the frequency response of a system or component is the locus of the tips of vectors, each of which gives the response in terms of amplitude and phase shift for a specific frequency. This representation of the frequency characteristics of a system or component is plotted in polar coordinates with frequency (an independent variable) as a parameter. Such a plot is normally called a Nyquist diagram, an example of which is shown in *Fig.* 9.

There are, however, other methods of representing this data which are easier to manipulate and interpret. Before examining these, note several characteristics of physical systems which are illustrated by the frequency response. The term "frequency characteristics," when applied to a physical system, refers to the magnitude and phase relationship between the input, or forcing function, and the output, or response function, when the time variation of the input is sinusoidal.

An ideal system would function so that for all angular frequencies ω within the range $0 < \omega < \infty$, the output response would correspond to the input; that is, the system response would be constant over the frequency range $0 < \omega < \infty$, and the phase shift would be zero within the same frequency range. No physical system can achieve this condition because of the energy storage and dissipation conditions encountered within it. All practical systems fulfill this condition only to a partial extent, as indicated by the Nyquist diagram.

Ability to respond uniformly to all frequencies would be the perfection needed in a control system that could reproduce the sharp corners and infinite rates of change found in the step disturbance. Fortunately, such performance is neither possible nor desirable when a system must do a good job of reproducing a signal at the output which carries

with it spurious signals called noise. The frequency of the noise usually occurs somewhat above the upper frequency of the true signals, so that to respond to the true and not the false, the control system is made to have a definite cut-off characteristic above a limiting frequency.

Actual systems will operate over a finite frequency band $0 \rightarrow \omega_{max}$, and it is within this band that frequency response studies have great value. At the low frequency end of the spectrum, the output to input ratio C/R approaches unity, and the phase angle ϕ approaches zero as ω approaches zero. However, as ω approaches infinity, the impossibility of instantaneous transfer of energy from one place in the system to another causes the ratio C/R to approach zero as a limit. Furthermore, as the frequency ω approaches infinity, the angle ϕ approaches $\pi n/2$ radians. The quantity n is an integer equal to the number of energy storage elements in the system or the order of the characteristic equation for the system. Thus a first-order system approaches a 90-degree phase lag or lead at high frequencies; a second order 180 degrees, etc.

A matter of great significance illustrated by the frequency response characteristic concerns the magnitude of the ratio C/R in the intermediate frequency range. As shown by the polar plot of *Fig.* 9, this ratio may be greater than unity. Such a characteristic, being a "gain" or amplifying consideration, naturally affects the stability of the system in this frequency range. Polar plots of frequency response of some common system components found in automatic control work are shown in *Fig.* 10.

Logarithmic Plots

Although analysis of control system performance is readily carried out through use of the Nyquist diagram, it is usually more convenient to plot the frequency characteristics on logarithmic co-ordinates. Such representation allows simple and less laborious methods to be used in determining steady-state performance, adjusting gain, and selecting compensating devices. Logarithmic plots of system transfer functions require plotting of only a few important frequencies out of the entire frequency range because straight-line or asmytotic approximations of the actual transfer-function loci can be made within acceptable error.

Other advantages of the logarithmic approach are; the many manipulations of polar transfer functions, which require vector multiplication and division, reduce to simple addition and subtraction operations; and the use of semilog graph paper serves to expand the low frequency range, which often is of the most interest.

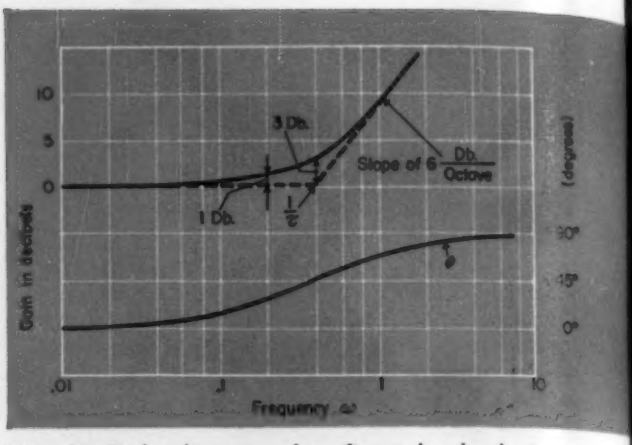

Fig. 11—Bode diagram of a first-order lead circuit. Log of the magnitude, and phase are plotted versus log of frequency. The decibel unit is defined as 20 times the logarithm of the magnitude ratio

Information required for analysis and design using logarithmic methods is basically the same as that required for the polar plot. Instead of plotting vector loci of the transfer function to a linear scale, the characteristics are plotted to a logarithmic scale. To exploit certain manipulative advantages, the amplitude and phase plots are made separately. The log of the magnitude is plotted versus log of the frequency; the phase is also plotted versus the log of frequency. The logarithm of the magnitude of the transfer function is commonly expressed in decibels, being defined as twenty times the common logarithm of the magnitude ratio.

Use of a logarithmic scale for frequency permits simple straight-line approximations for each curve, as shown in *Fig.* 11. The abscissa is plotted to a logarithmic scale with the numerical value of ω given. In this curve the following approximations are used:

$$1 + j\omega\tau = 1 \text{ for } \omega\tau < 1$$

$$1 + j\omega\tau = j\omega\tau \text{ for } \omega\tau > 1$$

These approximations produce straight lines on the logarithmic plot. Slopes of the straight-line approximations may be determined as follows.

The transfer function as a function of frequency expressed in decibels becomes

$$A_{db} = 20 \log_{10} (1 + j\omega\tau) \quad \ldots\ldots (18)$$

For low frequencies when $\omega << 1$, this expression is approximated by

$$A_{db} = 20 \log_{10} 1 = 0 \quad \ldots\ldots (19)$$

and is a straight horizontal line on the logarithmic plot. For high frequencies when $\omega >> 1$, Equation 19 reduces to

$$A_{db} = 20 \log_{10} j\omega\tau \quad \ldots\ldots (20)$$

Equation 20 can be shown to be a straight line

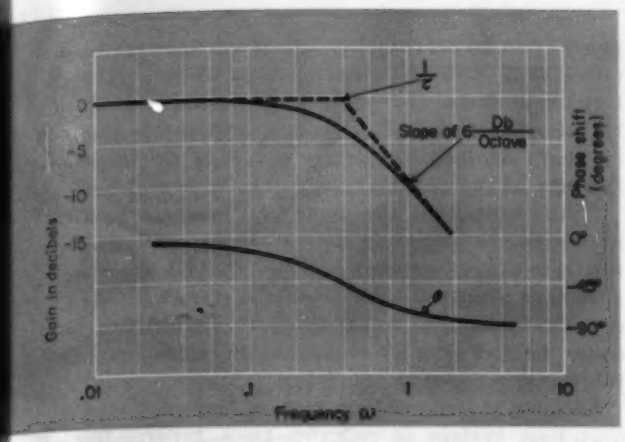

Fig. 12—Bode diagram of a first-order lag circuit which is the inverse of the first-order lead. At break frequency in first-order lag and lead circuits, the phase lag or lead is 45 degrees

with a slope of six decibels per octave (an octave is any doubling of frequency) by substituting values.

$$\text{For } \omega\tau = 1, \text{ then } 20 \log_{10} 1 = 0$$

$$\text{For } \omega\tau = 2, \text{ then } 20 \log_{10} 2 = 6 \text{ db}$$

$$\text{For } \omega\tau = 4, \text{ then } 20 \log_{10} 4 = 12 \text{ db}$$

Therefore, the slope of the high-frequency straight line approximation is six decibels per octave.

The point where the two straight-line approximations intersect is called the break or corner frequency and is equal to the frequency $\omega = 1/\tau$. The actual value of the magnitude at the break frequency is $\sqrt{2}$, for which the logarithmic value is

$$A_{db} = 20 \log_{10} \sqrt{2} = 20 \ (\tfrac{1}{2}) \ 0.3 = 3 \quad \ldots\ldots\ldots (21)$$

Thus at the break frequency the error due to the approximation is greatest and is equal to three decibels. It can also be shown that for a frequency equal to one-half of the break frequency the error will be 1 decibel, and for twice the break frequency the error is also equal to 1 decibel. These three points and the asymptotic approximations are usually all that is needed to sketch the actual magnitude curve to acceptable accuracy.

On the basis of this analysis, and since a first-order lag is merely the inverse of the first-order lead, it is evident that the logarithmic plot of a first-order lag would be as shown in *Fig.* 12. This is easily derived since the transfer function as a function of frequency expressed in decibels becomes

$$A_{db} = 20 \log_{10} 1 - 20 \log_{10} (1 + j\omega\tau) =$$
$$- 20 \log_{10} (1 + j\omega\tau) \quad \ldots\ldots\ldots\ldots\ldots (22)$$

For transfer functions expressing a pure integral response ($KG = 1/j\omega\tau$) or pure derivative response ($KG = j\omega\tau$), the amplitude expressed in decibels would be the same as that expressed by Equation 20. For terms of this nature the plot is a straight line with a slope of 6 decibels per octave, with a value of 0 decibels at some frequency ω so that $\omega\tau = 1$ as shown in *Fig.* 13.

Frequency-response curves of second-order lead or lag transfer functions may also be approximated by straight-line asymptotes. Such a transfer function may be expressed as

$$KG = [(j\omega\tau_y)^2 + 2 \xi j\omega\tau_y + 1]^{\pm 1} \quad \ldots\ldots\ldots\ldots\ldots (23)$$

where

$$\tau_y = \frac{1}{\omega_n}$$

If the roots of KG are considered to be complex ($\xi < 1$), then for $\omega\tau_y << 1$ the magnitude of the second-order lag reduces to

$$A_{db} = - 20 \log_{10} 1 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

For $\omega\tau_y >> 1$, equation 25 reduces to

$$A_{db} = - 20 \log_{10} | (j\omega\tau_y)^2 | = - 12 \text{ db per octave} \quad (25)$$

The two asymptotes can be drawn as shown in *Fig.* 14. In this case the greatest error between the actual curve and the asymptotic approximations is also at the break frequency. The exact amount of the error depends upon the value of the damping factor ξ since the magnitude of the quadratic term of Equation 23 is in general

$$- 20 \log_{10} [(1 - \omega^2 \tau_y^2)^2 + (2 \xi\omega\tau_y)^2]^{\frac{1}{2}}$$

The shape of the actual amplitude in decibels is shown for various values of ξ.

No simple linear approximations can be made in plotting phase lags or leads of the respective transfer functions which have been considered. However, the labor involved in plotting phase angles is not excessive once the basic phase characteristics of the various types of transfer functions become familiar through repeated use.

Since the complicated transfer function may be factored into a combination of six basic types of transfer functions discussed in the second article of this series, these basic curves are all that are required in control system design. The logarithm of the complete transfer function is merely the algebraic sum of the logarithms of its factors, and the complete phase characteristic of the overall transfer function is the algebraic sum of individual phase curves. Frequency response of the complete transfer function may be sketched approximately by using these techniques or it may be solved implicatively by substituting for selected frequencies. Actual frequency response curves or so-called *Bode* diagrams will not be presented here for complex combinations since they will be used in later discussions concerned with actual system design.

▶ Open and Closed-Loop

As previously emphasized, a control system involves several components acting in series so that the output of one is the input of the next. A system composed of four components connected in ser-

ies has been shown in *Fig.* 3. If a sinusoidal input signal were impressed on each component, their responses could be expressed in vector form. For the controller

$$\frac{C_1}{R_1}(j\omega) = A_1 \angle \phi_2 \quad \ldots\ldots (26)$$

For the valve

$$\frac{C_2}{R_2}(j\omega) = A_2 \angle \phi_2 \quad \ldots\ldots (27)$$

For the process

$$\frac{C_3}{R_3}(j\omega) = A_3 \angle \phi_3 \quad \ldots\ldots (28)$$

For the measuring element

$$\frac{C_4}{R_4}(j\omega) = A_4 \angle \phi_4 \quad \ldots\ldots (29)$$

If these components are connected in series, the ratio of the output of the series arrangement to the input forcing function can be found by taking the product of the individual ratios.

$$\frac{C_1}{R_1}(j\omega)\frac{C_2}{R_2}(j\omega)\frac{C_3}{R_3}(j\omega)\frac{C_4}{R_4}(j\omega) = (A_1 \angle \phi_1)(A_2 \angle \phi_2)(A_3 \angle \phi_3)(A_4 \angle \phi_4) \quad \ldots\ldots (30)$$

Because these components are connected in series, $C_1 = R_2$, $C_2 = R_3$, and $C_3 = R_4$. The ratio of the output of the series arrangement to the input by the rules of vector manipulation becomes

$$\frac{C_4}{R_1}(j\omega) = A_1 A_2 A_3 A_4 \angle \phi_1 + \phi_2 + \phi_3 + \phi_4 \quad \ldots (31)$$

Thus the total phase shift is the sum of the individual phase shifts, and the total attenuation is the product of the individual attenuations.

Also, since the transfer function of each component can be represented by a frequency-response curve, it is obvious that the overall system characteristic becomes the product of all the individual transfer functions. The product obtained is known as the open-loop frequency response or transfer function as the case may be.

If the output of the measuring element is connected to the summing device of the controller in the series arrangement of *Fig.* 3, the open-loop system is changed to a closed-loop system. As a closed-loop system it possesses characteristics peculiar to that type of arrangement, which must be taken into account in its design.

Suppose the closed-loop system formed from the open-loop system is redrawn as a general block diagram shown in *Fig.* 15. The controller, valve, and process characteristics are combined into the forward loop components $g_1 g_2$, and the measuring element is represented by h, the feedback component. By definition

$$R - b = e \quad \ldots\ldots (32)$$

Also

$$\frac{b}{C} = h \quad \ldots\ldots (33)$$

and

$$\frac{C}{e} = g_1 g_2 \quad \ldots\ldots (34)$$

By substitution, the ratio of the output C to the input R is found to be

$$\frac{C}{R} = \frac{g_1 g_2}{1 + h g_1 g_2} \quad \ldots\ldots (35)$$

Equation 35 is known as the closed-loop transfer function and by its use the closed-loop characteristics of a control system may be obtained immediately from the system configuration.

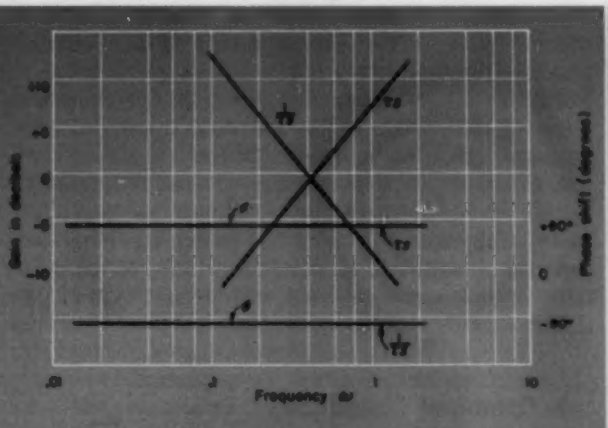

Fig. 13—Bode diagram of integral and derivative response. The phase angle is a constant lag or lead of 90 degrees over the complete frequency range

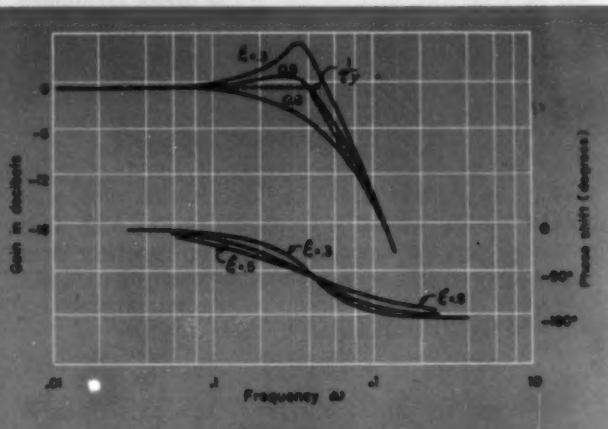

Fig. 14—Actual phase angle of second-order frequency response curves depend on value of damping factor ξ. These curves pass through −90 degrees at break frequency; maximum phase angle is 180 degrees

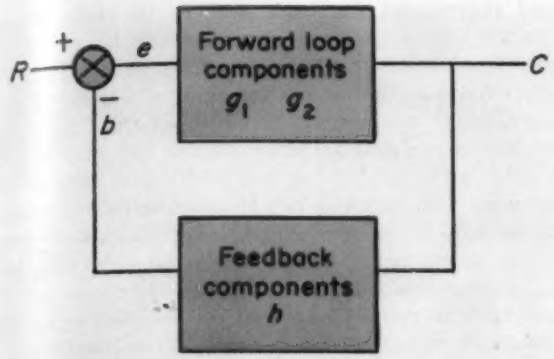

Fig. 15—Block diagram combining the elements of a closed-loop system into forward-loop components and the feedback component. This diagram is used to develop the closed-loop transfer function

Stability

The characteristic usually desired in a process control system is that zero error be maintained at all times. This characteristic follows from the fact that the primary purpose of a control system is to control a variable to a desired value or state. Control systems do this by making the error or difference between the actual state and the desired state of the controlled quantity approach a minimum. Because of the presence of stored energy throughout various parts of the system and because of the random nature of time variations of command or load changes, it is never possible to maintain zero error continuously in the dynamic state.

Systems in which the motion of the controlled variable is random or erratic and not responsive to the reference input function, or systems in which undesired self-sustained oscillations of the controlled variable are present, are said to be unstable. Instability gives unsatisfactory performance; it is necessary that the transient response of the control system to any disturbance be a decaying one that vanishes after a reasonable length of time. A system which possesses decaying transients is said to be stable. Such a system is a prerequisite since instability, if allowed to continue, leads to undue wear or even system failure in addition to unsatisfactory control.

Study of closed-loop system stability is generally given extensive treatment as a separate topic of the Nyquist criterion.[3] An extensive treatment of this criterion is beyond the scope of this discussion and, fortunately, is not necessary since the results can be stated simply.

The Nyquist criterion relates the nature of the transfer function response plot for sinusoidal input frequencies to the location of the roots of the system characteristic equation. This criterion for stability is based on correlating the position of the roots on the complex plane with the frequency response curve. A simple statement of the criterion is that a system is stable if the loop frequency-response curve does not enclose the −1 point on the Nyquist diagram.

A practical interpretation of this statement may be obtained if the action of a closed-loop system is examined closely. Control of the output of a system by a signal which depends upon the error between input and output is the basic reason for the accuracy of a closed-loop control system. In order to increase this accuracy the gain of the system may sometimes be increased. However, when an error signal is amplified sufficiently, the system will almost always develop a continuous oscillation with no external input being required. An oscillation of the signal being fed back when the input is fixed means that the error signal must be simply the fed-back signal itself, changed in sign.

The error signal, however, is transmitted through the components of the system to produce this signal. This transmission must, for sustained oscillation, involve shifting the error signal by −180 degrees and keeping the net amplitude ratio unity. Restated this means that for sustained oscillations the open-loop frequency response must have a gain of unity and a phase shift of −180 degrees. A phase shift of −180 degrees and a gain of unity on the Bode diagram will correspond to the −1 point on the polar plot of the frequency response and is known as the stability limit of the system.

For gains greater than unity at a phase shift of −180 degrees, the response of the system will be unstable. Conversely, for system gains of unity and a phase shift of less than −180 degrees the system will be stable. Therefore, as long as the sum of the phase shifts of the various components of a control system are less than −180 degrees for a particular frequency and the product of all component gains are unity at that same frequency, the system will be stable. The amount of phase lag less than −180 degrees possessed by the system for a gain of unity determines the degree of oscillation in the system response. The frequency at which this occurs is the frequency of the damped oscillations in the response.

Since measure of the effectiveness of the control system is closely identified with its stability, this criterion is a powerful tool in the design of automatic control systems. The frequency response method is extremely valuable because it suggests the change necessary in a system to improve its performance. The effectiveness of its use will be demonstrated in later discussions concerned with the analysis of specific process control systems.

The next article in this series is designed to develop an understanding of controller operation and to assist in visualizing controller utility. Various control modes in common use will be defined in terms applicable to the systems approach of this article.

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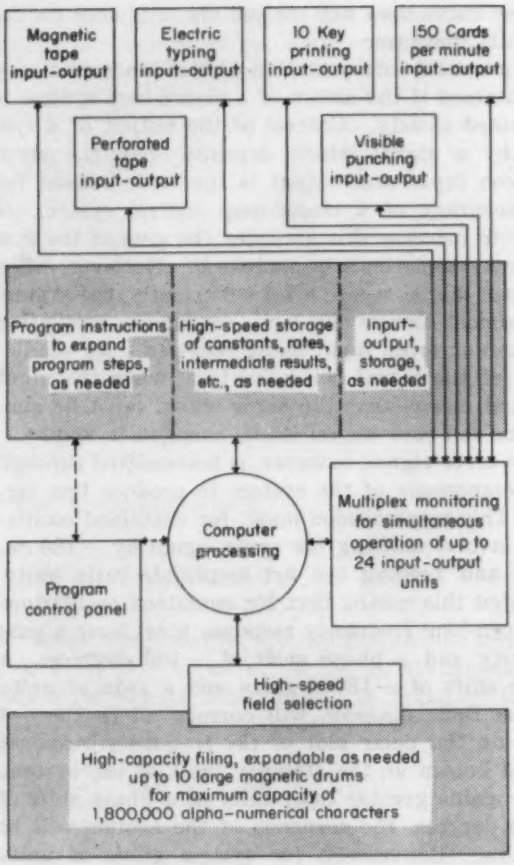
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High-speed storage of constants, rates, intermediate results, etc., as needed
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Computer processing
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PROCESSOR HANDLES

PRODUCTION DATA

AUTOMATED data processing is the modern solution to problems of obtaining timely information from masses of data. Adding human effort in proportion to the bulk increase in raw facts merely intensifies difficulties in co-ordination; economic considerations need not even be mentioned. Hackneyed methods of data processing handle too little data and produce needed information too late—all at excess cost.

A centralized data handling device designed to provide industry with prompt analysis from masses of data has been developed by providing a computer with increased storage, increased input-output facilities and improved data access ability. Unusual versatility has been achieved in this Univac File-Computer of Remington Rand by combination of tested methods for magnetic filing, flexible programming, multiple input-output operations in several codes, and electronic computing.

One example of the potential is in machine loading and scheduling operations. Master operations decks of punched cards could be pulled from file and reproduced for each part to be made for a specific order. These cards would be fed into the File-Computer where standard hours required are extended, and start and completion dates automatically computed. Productive time required by weeks or manufacturing periods can then be referred to the proper location in the magnetic drum storage. The machine can be programmed to signal production schedule overload condition in any given week, or to reject cards indicating jobs affected by the overload condition. Immediate read-out is available to provide constant information as to the condition and spread of backlog in the plant.

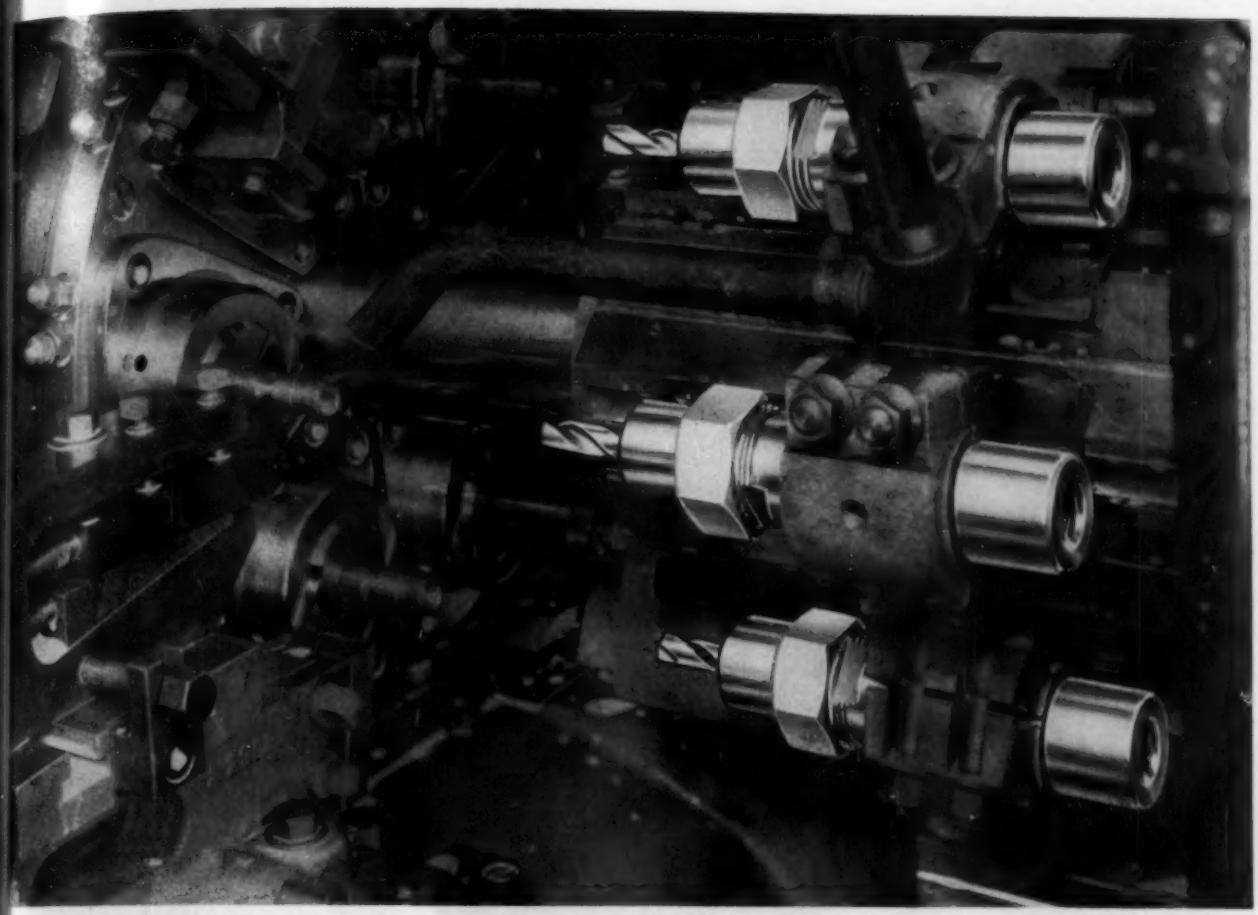
This scheduling and loading is done with the cards in job-order sequence. It is not necessary to sort the cards by department or machine center. If an overloaded condition is indicated, all operations cards pertaining to a specific order are together, eliminating the time consuming job that must be done by present methods to find all operations cards for a specific order, and bring them together before re-scheduling.

Information on jobs comprising the load can be sorted on the drums and drawn off in the form of printed reports to act as shop schedules. In addition, the tabulating cards used as input media to machine loading can also be utilized to prepare job tickets.

After work has been completed in the factory, quantity produced and actual time can be punched into the job cards, and the cards fed back into the computer without sorting to record production achieved against quantity scheduled. This information can be drawn off in the form of daily production reports for distribution to all interested parties. Because this data is readily obtained at high speeds, the computer supplies the solution to the problem in obtaining current and timely daily production reports.

In the control of raw materials and component parts, and assembly inventories, the File-Computer makes available a method of recording inventory data without need for prearrangement of data in numerical sequence. Pertinent data as to requirements, open replenishing orders, available balance and actual balance can be stored on the drum. Input information can be fed directly to the computer, and immediate access is available for reading out the quantity of any item of inventory. The computer can be programmed to signal quantity below the review point and to report those items that are critical. In addition, a requisition can be price extended and inventory relieved in one operation, without putting the cards into any particular sequence. For companies with heavy daily activity of incoming orders, both of these functions can be performed simultaneously.

Because of the multiplexing feature, as many as 24 input units can be handled at the same time, allowing for a flexibility and speed of management reporting seldom attained. Management can be provided with reports that are timely and effective, make savings in operating costs, and realize constant aim of management—the definite edge on competition.



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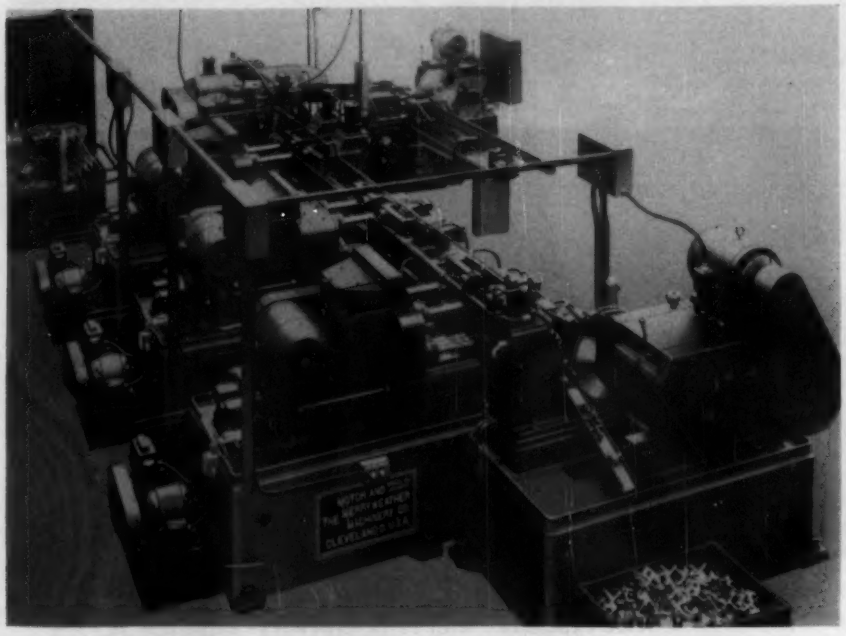

AUTOMATIC TRANSFER MACHINE

New 15-station in-line type transfer machine uses standard machine units for processing a refrigerator cylinder bracket. Bracket is produced from standard 3 by 2½ by ½-inch hot-rolled angle iron at a production rate of 380 pieces per hour. First station saws the angle iron to accurate length so that three equal length pieces can be discharged at the final station. Saw unit discharges the piece into a lateral conveyor for loading by index into the main straight-line transfer machine. At the first machining station the angle iron section is milled on one face and one edge. From this station the part is moved into the first barrel type turnover fixture, then to the second machining station for milling the other face and edge. The next station drills and reams three holes. Following the drilling and reaming, 12 holes are drilled and six holes reamed by a similar drill-ream setup. The drilling and reaming are followed with a second barrel type turnover fixture which positions the parts for the end milling of seven holes. The milling, reaming and drilling stations are equipped with 15-hp way type power units, with multiple spindle heads. At the last station, a saw head equipped with two circular saw blades cuts the stock into three completed pieces. Machine units are hydraulically actuated and electrically controlled, including safety limit switches at each station. Bottom of the main base is open for a floor type coolant sump and chip conveyor. Special piping provides intermittent air jet and heavy coolant wash to prolong tool life and to wash chips from the work and transfer rails. A tool board is provided for automatic tool cycle control, tool storage and presetting gages for all tools. **Motch & Merryweather Machinery Co.**, 888 E. 70th St., Cleveland 3, O.

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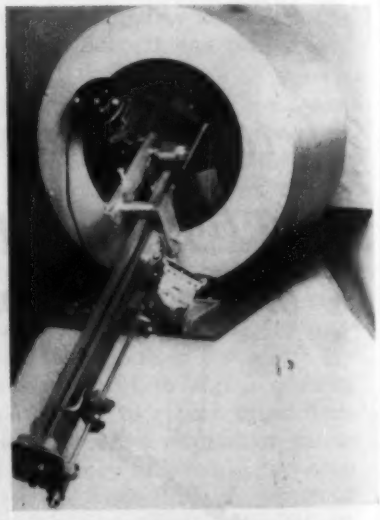
FEEDER AND COUNTER

New machine, called Feed-A-Matic, can be used as a hopper to feed parts in an orientated manner for assembly or machine operations. It can also be used for packaging by providing it with mechanical release fingers for small counts or with an electronic system for larger counts. Feed-A-Matic will handle items such as screws, nuts, washers, nails, lock washers, beads, plastic parts, die cast parts, screw machine parts, pharmaceutical tablets, pills and capsules. Production rates up to 200,000 parts per hour are available, depending upon the size and shape of the part being hoppered. Unit consists of a cast iron or aluminum barrel with cast-in pockets. For pharmaceutical or food products, the aluminum barrel is plastic coated. As the barrel slowly revolves, the items slide into the pockets. There they are trapped by means of a stationary plate which gradually covers more and more of the pocket opening as the pocket revolves up to the top position. At this point the



covering plate ends, allowing the parts to flow down a chute which orientates them. Parts not properly orientated are rejected back into the hopper by means of a revolving wheel. Parts can not lock or jam the hopper. Changeover is made by adjusting the space between the rails by turning a small screw. Unit is driven by means of a 1/15-hp motor. Several hoppers can be combined with a turntable or other conveying system to provide a complete packaging or assembly operation. **U. S. Engineering Co.**, 40-24 22nd St., Long Island City 1, N. Y.

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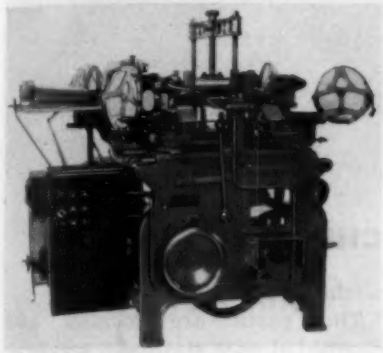

THERMOPLASTIC STAYER

Automatic corner cutting and quad staying operations are combined by attachment of a new corner cutting device to Kingsbury & Davis Model LS thermoplastic quad stayer. Scored blanks are fed directly into the stayer hopper. Operating at regular speed, the machine cuts four corners simultaneously and immediately drops the blank into the forming die where it is stayed. Because the corner cutter is readily accessible at the top of the stayer, cutting knives can be adjusted to conform to changes in box sizes. Knives are electrically actuated, eliminating need for mechanical linkage between cutters. Combination of two operations into one is said to provide savings in both labor and space. One operator can run two stayers, and no additional equipment for this operation is needed. **Stokes & Smith Co.**, 4992 Summerdale Ave., Philadelphia 24, Pa.

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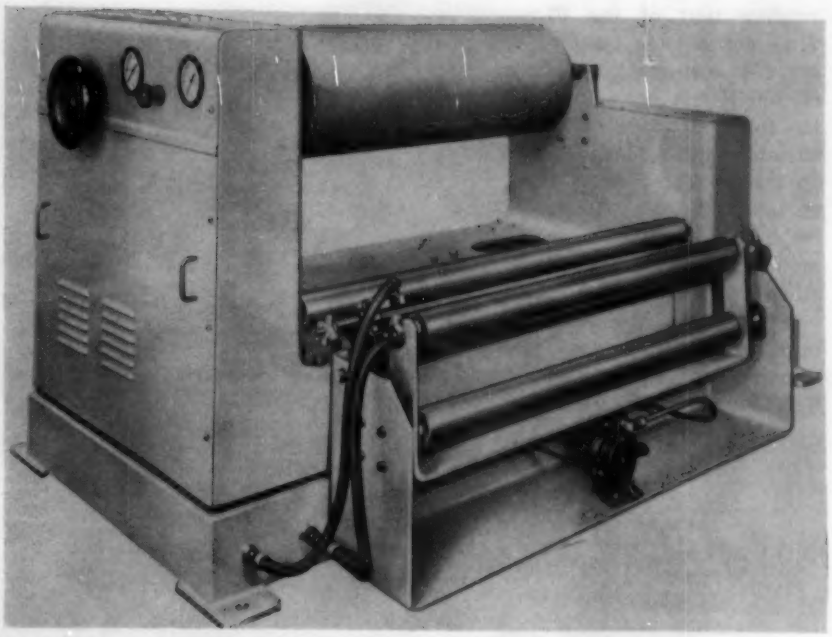

BACKSTAND FOR WEB CONTROL

New backstand controls tension and edge position of a moving web as it is fed to a rewinder, slitter, converting machine or printing press. Tension may be maintained at any selected value up to 4 lb-inches within 5 per cent at a steady web speed. Edge position is maintained within 0.015-inch with a run-out of ± 3 inches from center position. Backstand operates at speeds up to 1200 ft per minute; larger model will accommodate a 2000 lb roll, 54 inches wide and 48 inches diameter. Tension control is completely hydraulic. Unwind stand and control systems are combined in an integral package which requires electrical and air connections for operation. Larger units may need water to cool the brake. **Askania Regulator Co.**, 240 E. Ontario St., Chicago 11, Ill.

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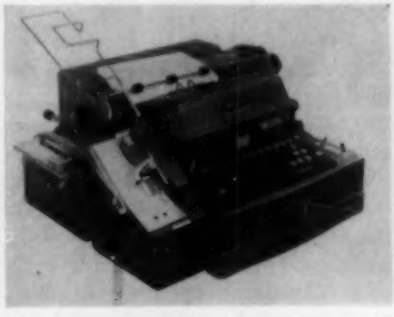
EDGE-PUNCHES CARDS

New Flexowriter reads edge-punched cards or punched paper tape and automatically prepares documents and by-product tape for data processing. Master record cards are edge-punched on the Flexowriter. These cards can be prepared automatically from previously edge-punched cards or punched tape, or they can be prepared by operating the keyboard manually. Cards can be edge-punched in continuous fanfold form and after this process, cut into one, two or three units for use. Codes can be punched in one or two edges. As cards are edge-punched, self-adhering labels can be typed for card identification; labels can also be typed automatically from the cards they are to identify by inserting edge-punched cards into the reading unit of the Flexowriter. When data required



in master records are too lengthy to record in cards, tape is used. The tape and cards are interchangeable. Tape can also be punched by a manual typing operation or automatically from previously punched cards or tape. When cards are completed, they are filed for use as required. For preparing a form and by-product tape for data processing, necessary edge-punched cards or tape are pulled from the file and inserted in the

reading unit of the Flexowriter. They control the machine for typing data automatically at the rate of 100 words per minute, spacing the form, stopping for insertion of variable data and punching selected data into by-product tape. Five-channel, common language tape which is used will also control metal plate embossing machines, standard communications equipment, tape-to-card machines and other data processing machines. **Commercial Controls Corp.**, 1 Leighton Ave., Rochester 2, N. Y.

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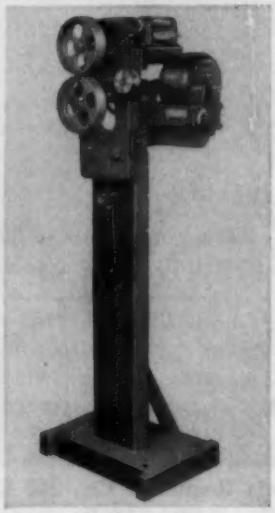

WIRE MEASURING UNIT

Machine which measures wire and cable footage at high speeds is designed for use in wire drawing, stranding or insulating lines. Machine counts from zero to any preset limit, emits an electrical impulse, reverses itself and counts back to zero. Process is repeated automatically without external reset. Electrical signal sent out by machine can be used to operate an audible or visible signal, to stop a take-up and pay-off combination, or to trigger the automatic reel cutover on a continuous take-up. Measuring machine will handle wire speeds up to 2500 fpm, and cables up to 2 inches in diameter. Maximum count for signal and automatic reversal is 80,000 ft. Accessory totalizing counter records amount of wire passing through the machine. **Davis-Standard Sales Corp.**, 14 Water St., Mystic, Conn.

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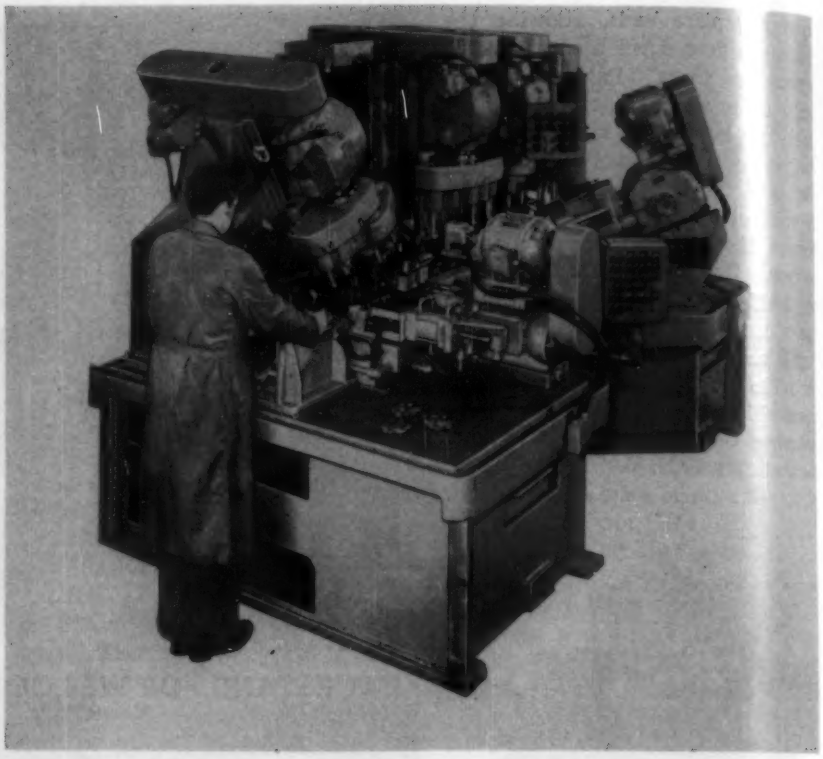

DRILLING AND TAPPING MACHINE

Designed and built for an automobile manufacturer, eight-station, multiple spindle, dual loading transfer type machine has five drill units and an air-hydraulic transfer mechanism. Machine will turn out 450 carburetor bodies per hour. Various drilling and tapping operations are performed on the machine.

The parts are located and clamped at each station in previously machined valve holes. Parts ride free on rails between stations. **Hartford Special Machinery Co.**, 287 Homestead Ave., Hartford 12, Conn.

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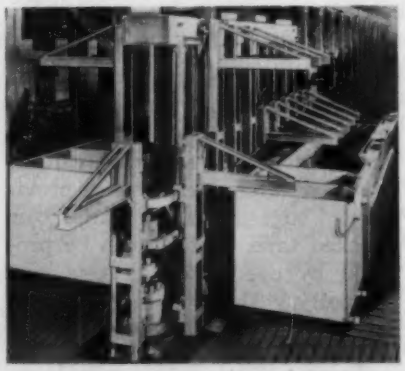

PLATER AND PROCESSOR

Side arm type machine which enables automatic loading and unloading can be adapted to single or double row plating and processing. Machine is designed to handle many rack sizes and extreme weights. Setdown mechanism which provides independent timing in one or more tanks is available, and additional transfers can be provided. Through use of a special timer control, carrier arm can be made to skip any particular tank or operation as desired. Another optional feature is a 20-inch or wider catwalk between processing tanks and the mechanism on two-row machines, permitting addition and removal of anodes, lubrication and inspection. No moving mechanism is over the solutions and all internal mechanisms are built below tank level. This eliminates metallic wear and contamination of solutions from excessive lubrication. Damage resulting from corrosive fumes is also reduced since moving parts are not in areas subject to attack. Lift and horizontal motion of the new machine is by hy-

draulic power. Special controls permit independent adjustment of acceleration and transfer speeds to accommodate many weights and rack sizes. **Frederic B. Stevens Inc.**, Detroit 16, Mich.

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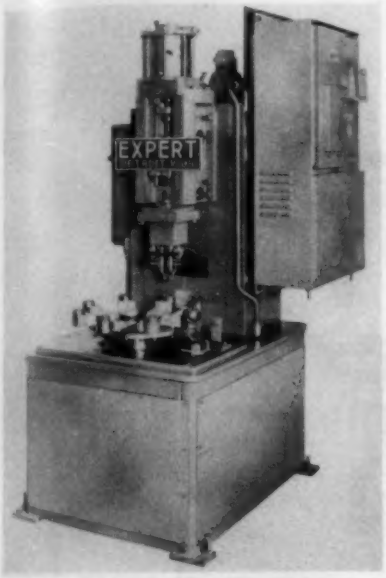

INDEXING MACHINE

Eight-station indexing machine designed for a variety of spot, projection and arc welding production operations will produce up to 720 welded assemblies per hour. Machine, which features an all mechanical drive, consists of a welded steel frame, a standard or special welding head, an electrical control cabinet, a 24-inch index table and a ½-hp, motor driven mechanical drive enclosed in the base of the machine. Although manually loaded, automatic index cycle and automatic part ejection are provided for the welder operation. Index table, mounted on tapered roller bearings, is driven by a simplified motorized cylindrical cam arrangement. Cam has a single groove that engages pins corresponding to the number of index positions. Smooth trapezoidal acceleration characteristics are provided in the cam. One-second indexes are possible with the table drive. Flexible fixture mounting design on the machine assures that no loads imposed by gun operation are transferred to the index table, prolonging table bearing life. When long dwells are required, a clutch

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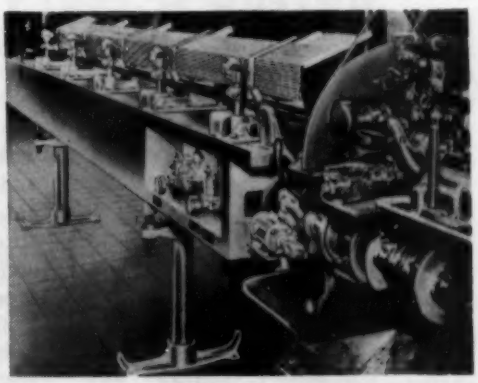

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LIPE-ROLLWAY CORPORATION
Syracuse 4, N.Y.

Send me free book on how to gear machine tools to the steady flow of Time.

Name ..... Title .....

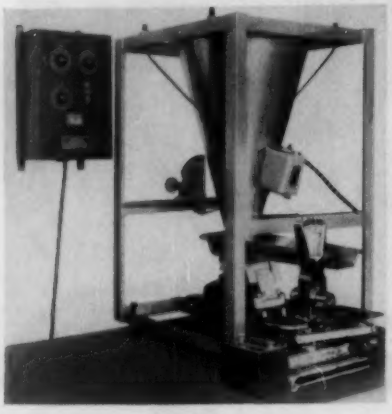
Company .....

Street .....

City ..... Zone ..... State .....

brake is added to the motor drive. Machine can be adapted for a variety of welding operations requiring six indexes and up by changing the cam and the follower plate. **Expert Welding Machine Co.,** 17144 Mt. Elliott Ave., Detroit 12, Mich.

Circle No. **9** *on Reply Card*

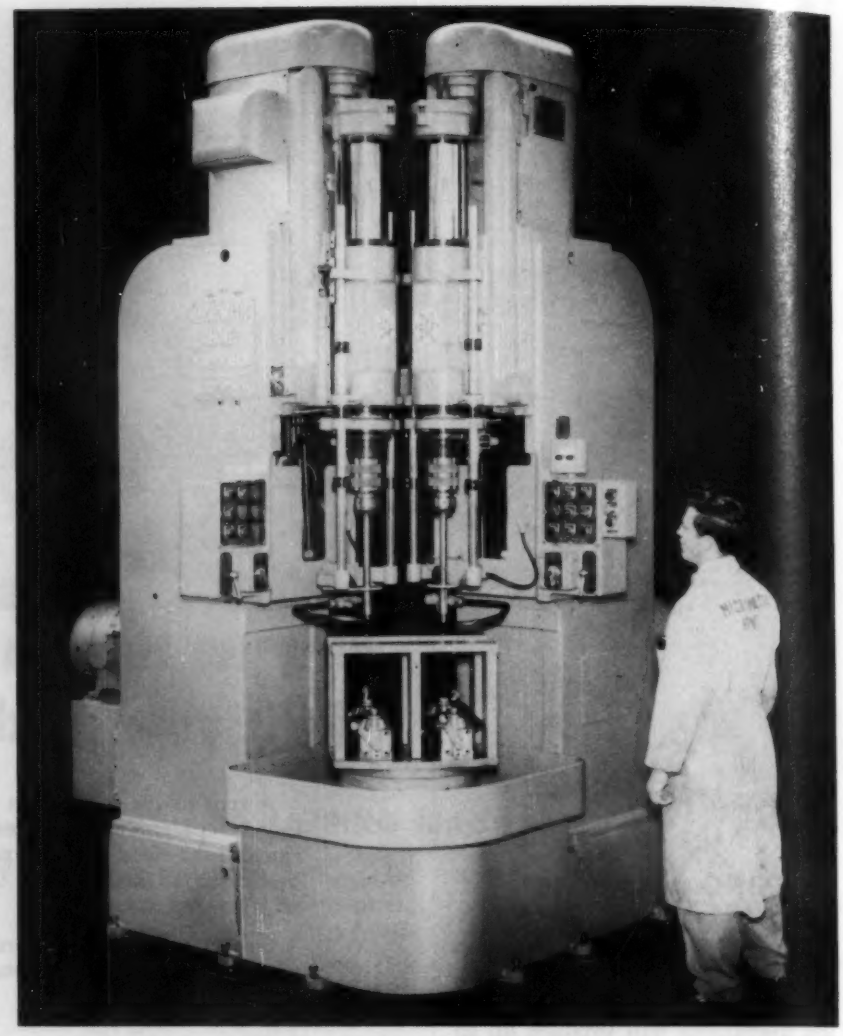


WEIGHING MACHINES

New line of semiautomatic weighing machines is designed for packaging, batching, bagging, compounding and feeding a variety of commodities. Scales give visual indication of every weighing as it is made. Scale unit is fed by vibratory feeders, with rheostat controls allowing adjustment of rate of feed for optimum weighing speed consistent with desired accuracy.

The models available include those feeding downward from vibratory bulk hopper, or upward by a spiralling vibratory trough from bowl feeder unit. Latter has proved well suited to feeding of small pieces such as screws, washers and pharmaceutical capsules, since the unit may be set to feed pieces to the scale one by one if extreme accuracy is desired. The scale controls feeder mechanism by a photoelectric cell, beginning weighing cycle upon operation of a starting button or foot switch. Initial feed is at the preset fast rate; then it is automatically switched by the scale to slow rate as the required weight is approached and finally off at the exact weight point. Scale illustrated measures weight from ¼ oz to 1 lb. **Exact Weight Scale Co.,** 944 W. Fifth Ave., Columbus, O.

Circle No. **10** *on Reply Card*



VERTICAL HONING MACHINE

Called the Hydrohoner, new vertical honing machine is equipped with automatic abrasive feedout and stone-wear compensation, and automatic sizing control. It has automatic coolant start and stop, and an automatic time cycle. Three-speed transmission assembly controls rotation on each unit. Reciprocation is hydraulically actuated, and speed is infinitely variable from 0 to approximately 60 sfpm. Automatic rotary index table controls are interlocked with machine controls to provide automatic indexing and operating safety. Four-station fixture makes it possible to hone two parts simultaneously while two stations are being unloaded and loaded. Same procedure can be used with one-station indexing to hone the same bore progressively, or two different bores in the same part. When Hydrohoner is adapted for finishing transmission converter reaction shafts, it achieves a 96-second cycle time. Open end shafts are 1.0835 to 1.0855 inside diameter and 7 inches long. Material is SAE 1052 seamless steel tubing, heat-treated. Stock removal is 0.004 to 0.005-inch, with 20 to 25 rms finish. It holds tolerances of 0.0005-inch for size, 0.0002-inch for roundness and taper and will turn out 46 to 56 pieces per set of honing stones. **Micromatic Hone Corporation,** 8100 Schoolcraft Ave., Detroit, Mich.

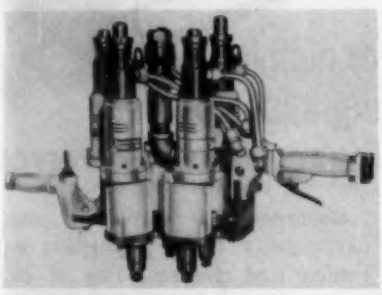
Circle No. **11** *on Reply Card*

LABELING MACHINE

Semiautomatic labeler for round containers handles a variety of container sizes. Machine features an automatic label feed in which the label is fed, gummed and applied to the container. Another

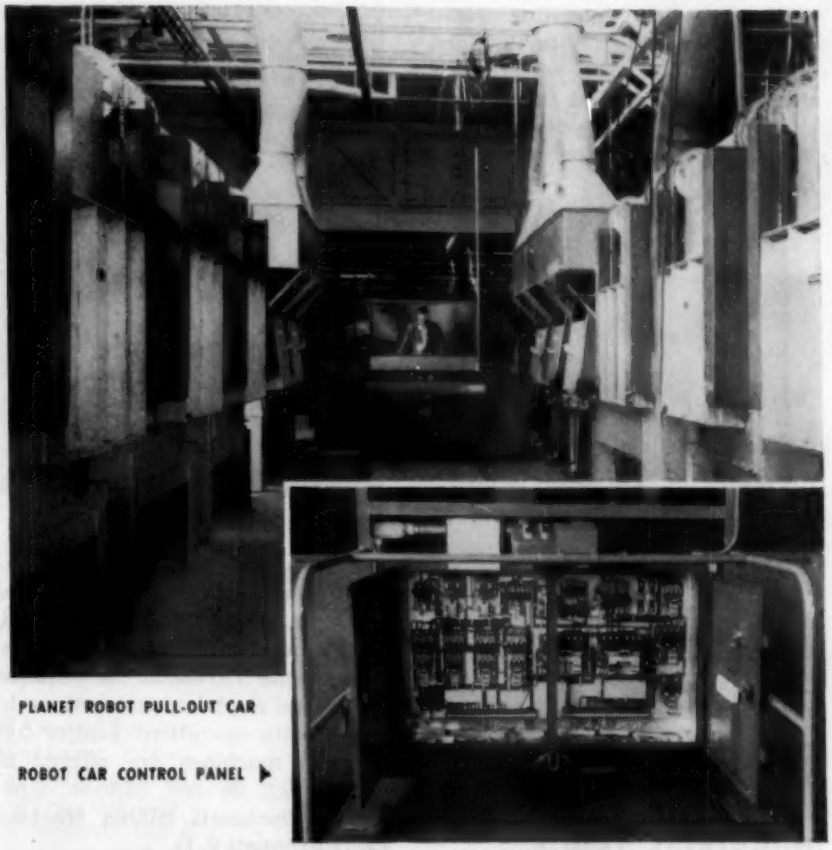
feature is the hinged frame glue reservoir which can be lifted out, making the entire glue mechanism accessible for either cloth or brush cleaning. Labeler will handle 4-oz bottles to 5-gal steel drums with a minimum diameter of 1½ inches and a maximum height of 13½ inches. Machine will take labels from 2 inches high by 3 inches long to 12 inches high by 18 inches long. Labeling machine will handle quart size or smaller containers at the rate of 15 to 18 per minute, gallon jugs at 10 to 12 per minute, and 5-gal round containers at 5 to 7 per minute. **Atlantic Supply Co.**, 16 N. Greene St., Baltimore 1, Md.

Circle No. **12** *on Reply Card*



NUT SETTER MOTORS

Twenty-eight new motor sizes and styles for a line of multiple nut setting tools make possible setting more closely than before grouped nuts and bolts and meeting all torque requirements from 4 to 190 ft-lb. Nut setter can be used to run from one to 10 nuts or bolts simultaneously, and each can be set to the same or different torques as desired. Each motor spindle has an integral torque regulator that can be adjusted easily over the entire range of the motor. Nut setter is designed for convertibility through standardization of components. Motor units, handles, manifolds and hose swivel can be reused when a new setup is



PLANET ROBOT PULL-OUT CAR

ROBOT CAR CONTROL PANEL ▶

to load and unload furnaces...
automatically...

Just Press A Button

This PLANET robot car, specially designed for heat treating operations at a large automobile plant, is completely automatic and entirely self-propelled. It loads and unloads trays of forgings weighing up to 600 lbs. from furnaces at *either side*, permitting a compact, space-saving installation.

Here's automation in action . . .

Trays are withdrawn from a right hand furnace and discharged into furnaces on the left. The entire cycle is handled by pushing one button.

If you have a materials handling problem, it will pay you to "Plan with Planet". Experienced Planet engineers design and install specially engineered systems complete from the preliminary survey and specifications to installation and testing.

Write today . . . for information on applying automation to your operations.

PLANET CORPORATION
1810 SUNSET AVENUE
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- CONVEYORS
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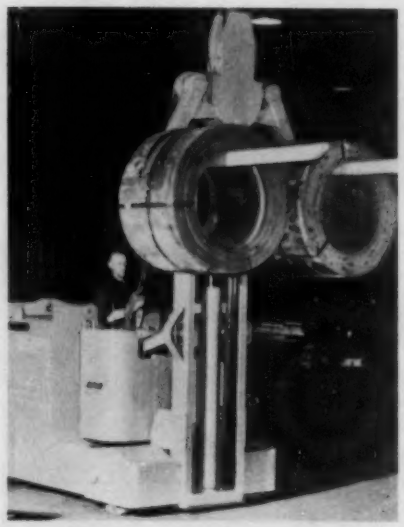
- FOUNDRY EQUIPMENT
- AUTOMATION
- STEEL FABRICATION

designed. Only mounting plate and air distribution tubing are changed. The plate which positions the motor units to the bolt pattern, is of ½-inch steel. **Keller Tool Div., Gardner-Denver,** Grand Haven, Mich.

Circle No. **13** *on Reply Card*



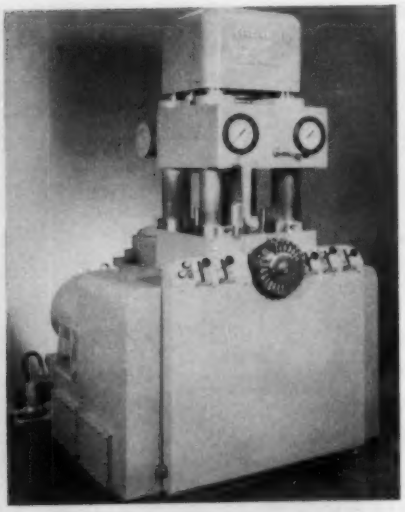
INDUSTRIAL TRUCK

Equipped for handling a variety of coil sizes and sheet packs, 15,000 lb capacity industrial truck features hydraulic split ram which acts as a single unit or as a pair of forks for handling one large coil or two smaller ones, and may be used with either gas or gas-electric powered trucks. Truck has contactor type controls mounted beneath the cowl, power steering, caster type trail axle, worm drive and hydraulic lift compounded with heavy duty roller chain. Length of the ram or height of the lift can be altered to suit individual requirements. **Elwell-Parker Electric Co.,** 4205 St. Clair Ave., Cleveland 3, O.

Circle No. **14** *on Reply Card*

HYDROFORM MACHINE

New hydroform machine will form parts from sheet metal blanks up to 8-inch diameter with a maximum draw depth of 5 inches. Hydroforming process uses a male punch and a flexible die member backed up by hydraulic oil presure which may be accurately controlled up to 15,000 psi. Many sheet metals in gages up to ¼-inch steel can be

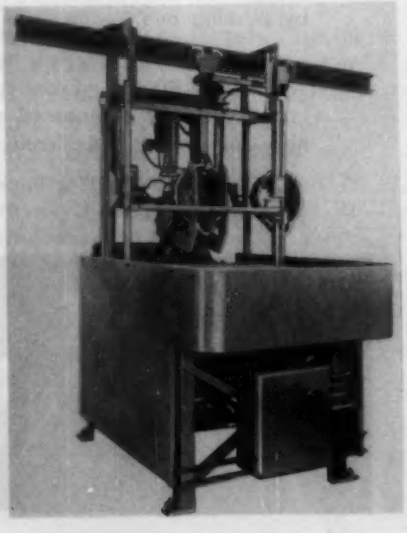


drawn by machine. Maximum machine operating rate is 200 cycles per hour. Machine is self contained, floor mounted, 5 x 5 x 7½ ft high, and weighs 12,000 lb. It requires water and electrical connections to be put into operation. Larger hydroform machines are offered in 12, 19, 23, 26 and 32-inch capacities. **Cincinnati Milling Machine Co.,** Cincinnati 9, O.

Circle No. **15** *on Reply Card*

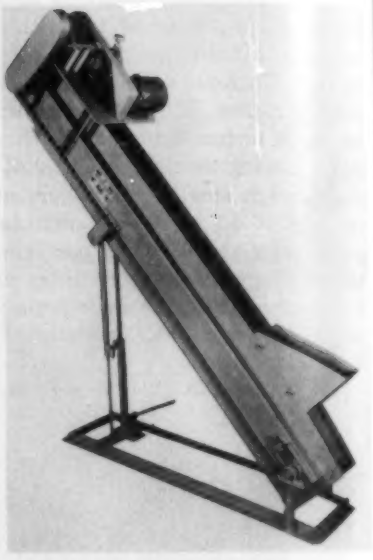
TRANSFER MACHINE

Designed to remove parts from the hooks of an overhead monorail conveyor and transfer them to a roller conveyor, conveyor transfer machine operates at a rate of approximately 300 pieces per hour. Machine can be arranged to select certain parts and reject all others from a conveyor which is carrying



different parts. It will als pick up parts from a roller conv or and place them on overhead onorail hooks, or pick up parts fr n either a roller conveyor or a onorail conveyor and place them a machine. Machine is adap ble to round parts similar to thos shown, and it can also be used t handle parts of other shapes as well as take baskets and boxes. **General Tool Co.,** Landy Lane, Rea ding 15, O.

Circle No. **16** *on Reply Card*



SMALL PARTS CONVEYOR

Designed for conveying small parts away from production machines and presses, line of conveyors features hydraulic ram adjustment at the discharge end for absolute accuracy of discharge height, and automatic trap loading to eliminate flipper gates, prolong life of the belt and prevent clogging. Conveyors are available in standard belt widths of 5, 8, 10 and 12 inches and have variable speeds from 30 to 90 ft per minute. Drive is by electric motor mounted on the upper end of the conveyor with a belt take up on the lower end. Unit has ball bearing construction throughout. Although designed for small parts (cleats on 6-inch maximum centers), machine can be modified to accommodate larger parts. Portable mountings are available. **Metzgar Conveyor Co.,** 408 Douglas St. N.W., Grand Rapids 4, Mich.

Circle No. **17** *on Reply Card*

Twenty-one years ago . . .

'Way back in 1934, The Bristol Company led the way in the field of automation by developing the Bristol Systems of Coordinated Process Control.

These systems automatically controlled and coordinated all of the variables and operations of a process—such as the time of operation of valves, pumps, blowers, dampers, and the control, at a definite value or according to a time program, of variables that affected the uniformity, quality, cost, and yield of a product – such as temperature, pressure, liquid level, flow, pH, humidity, and speed.

RESULTS: They eliminated variations in processing that caused inefficiency – cut down rejections and waste – insured product uniformity – helped cut processing time as much as from 10 days to less than 30 minutes. And these systems quickly paid for themselves.

A REVOLUTIONARY CONCEPT: They brought automatic plant operation to a startling reality and were hailed at the time as a fundamentally new development – which would in time revolutionize manufacturing.

Today, Bristol Coordinated Control Systems are used in the chemical, oil refining, rubber, tobacco, textile, steel, metal working, food, paper, the automotive industries, and many others. They are so completely automatic that it is only necessary to push a button to start up, another to shut down.

The modern solution to processing and manufacturing control problems

Bristol's System of Coordinated Process Control is made possible only by the following unique combination of facilities, which have been developed during 66 years of building and applying thousands of automatic control systems and instruments in practically all industries:

1. The complete line of modern Bristol Automatic, Controlling, Recording, Electronic, and Telemetering Instruments, representing some of the most advanced ideas in instrument engineering.
2. Bristol's Fully-Automatic Time-Cycle Controllers or "Mechanical Brains".
3. Bristol's ability to combine electronics and the mechanical phases of automation.
4. The ability and facilities of Bristol's engineering staff, gained by long experience and Bristol's pioneering work in the field of automation.

Bristol Application Engineering is at your service:

Our application and field engineers are ready to solve control problems involving automation and Coordinated Process Control Systems by working jointly with your research, development, and plant engineers.

Have you an automation problem?

Our application engineers and nation-wide group of field engineers would like an opportunity to work with your technical staff on any problems of automation for which Bristol Controlling and Recording Equipment and Bristol Coordinated Control Systems appear to be the solution. 5.3

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Automatic Controlling, Recording, and Telemetering Instruments for:

Pressure, Vacuum, Absolute Pressure, Draft, Differential Pressure, and Barometric Pressure.
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Flow, Water and Liquid Level, and Specific Gravity.
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Speed of Travel and Rotation.
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Mechanical Motion, Position and Operations

Including:

Automatic Control Systems
Electronic Potentiometers
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Time-Cycle Controllers
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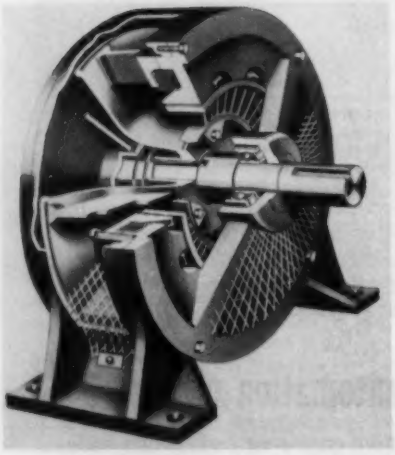
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

AUTOMATION new components

Parts, elements and devices designed for creating more automatic systems



Air and Liquid Cooled Brakes

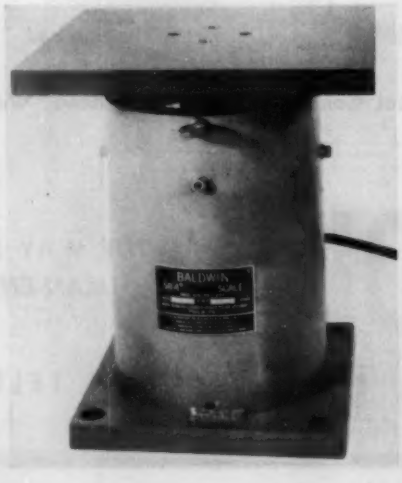
Although most commonly used to provide a controlled load, air and liquid cooled eddy current brakes have applications for unwind stands in metals, fabric, plastic and paper. High inertia masses are stopped through controlled deceleration. Artificial loading in numerous applications permits speed control of certain machine tools and crane hoists. Open support housings provide unrestricted air flow for adequate cooling in air cooled model (above). Air is drawn in through the end housing and across the drum. Generated heat is transferred to the air stream, and then exhausted from the drive periphery by a fan that is an integral part of the rotating drum. In the liquid cooled model, the coolant inlet in one of the end housings is positioned to carry the liquid into an annular trough in the drum support. Centrifugal force drives the coolant along the inner surface of the drum. The coolant then discharges into a chamber outside the drum and flows to the bottom of the outer casing and into a gravity drain. Eddy current brakes have no mechanical contact between the rotor and stationary field, thus providing smooth and shock free operation. **Dynamatic Div., Eaton Mfg. Co.**, Kenosha, Wis.

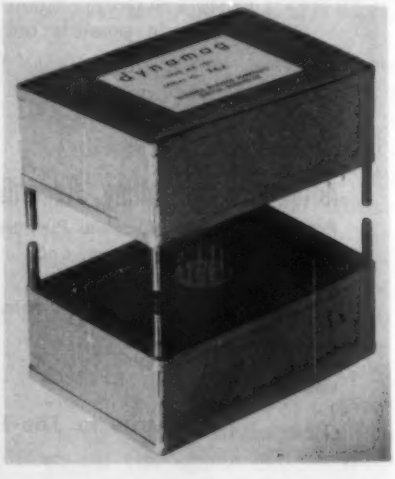
Circle No. **18** *on Reply Card*

Platform Scale

Electrical weighing with automatic control of flowing powdered materials in hopper carts is an application of floor level platform scale. Scales of 500-lb capacity can be set in a pit 10½-inches square and less than 12-inches deep. A 10-inch square platform is provided. Variety of instrumentation can be used with the scale, including indicators, recorders, and control equipment. A single direct reading dial indicator and seven signal lamps are used with seven scales in one application. Lamps indicate predetermined weights on each scale at which material feed valves are turned off automatically. Dial indicator can be switched to any scale circuit. Electrical platform scale incorporates a single load cell of compression type in which bonded resistance wire strain gages are the load sensing elements. Cell supports a platform on a short column which is held vertical by two sets of radial flexure straps. Accuracy of weight is assured by permitting only vertical applications of load regardless of the location of the load on the platform. **Baldwin-Lima-Hamilton Corp.**, Philadelphia 42, Pa.

Circle No. **19** *on Reply Card*



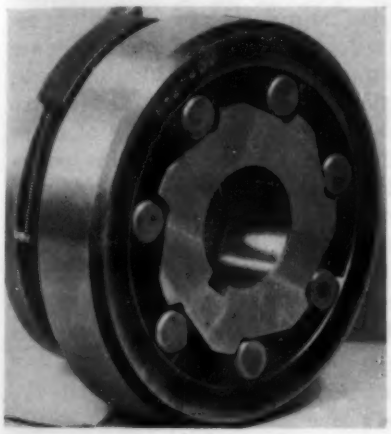


Magnetic Amplifier

A dc magnetic amplifier is suited to driving electrohydraulic valves, mixing signals where low zero drift and zero error are specified, and to automatic control, instrumentation, and computer applications. Combined infinite internal gain and external current

or voltage feedback maintains linearity over a wide load variation. Unit is insensitive to 10 per cent changes in supply voltage and frequency, and requires a 1.5 w, 20 v rms, 1000 cycles per second power supply. Input impedance is variable up to 50,000 ohms for use with thermocouples, strain gages, photoelectric cells, and demodulators. Obtainable power gains with voltage or current output range up to 5000. Amplifier performs addition and integration of multiple inputs, and a low impedance input adapts it to transistor circuitry and induction and photoelectric pickups. Additional features are potted construction, plug-in connector, and four tie-down studs. **Dynamics Research Associates,** 414 Times Square Bldg., Seattle 1, Wash.

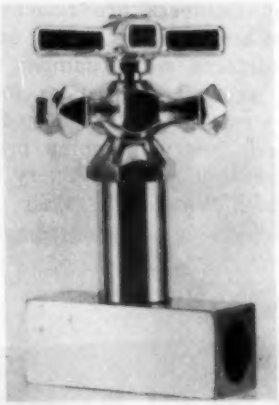
Circle No. **20** *on Reply Card*



Single Revolution Clutch

A new single revolution clutch supplements company's line of regular clutches, is designed for flywheel mounting on riveting and fastening machines, staplers, small punch presses, and similar machines. New clutch features a minimum of parts and direct acting trip control. The absence of the levered trip, used on company's regular clutch line, makes the new assembly suitable for heavy duty service and high speed operation. This clutch is not recommended for light duty or slow speed where one of the regular models would serve. It is available in five sizes, and capacities range up to 1146 ft-lb torque. **Hilliard Corp.,** 100 W. Fourth St., Elmira, N. Y.

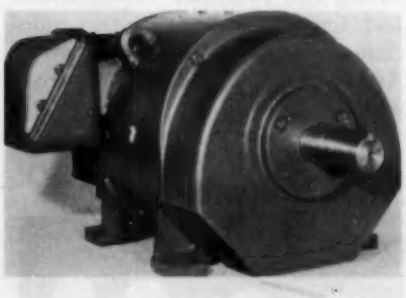
Circle No. **21** *on Reply Card*



Flow Control Valve

Coaxial metering flow valve combines in one unit the functions of both a precision metering valve and by-pass valve. Capable of quick vernier adjustment to provide an accurate flow of liquid or gas under constant pressure, the new valve is designed for hydraulic and pneumatic systems with pressures up to 5000 psi. Applications include flow meters, and pump and valve systems where by-pass flow must be regulated in laboratory equipment, fuel systems, fire control systems of weapons, steam throttling, aircraft, guided missiles, motored servomechanisms, automation equipment and similar apparatus. Valve is available from $\frac{3}{8}$ through $1\frac{1}{2}$-inch NPT and in manual and motor driven types. **Ard Mfg. Corp.,** 85 Tremont St., Meriden, Conn.

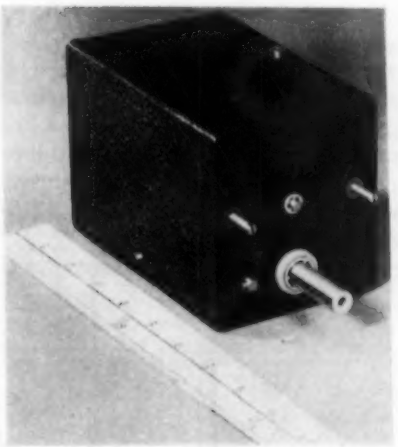
Circle No. **22** *on Reply Card*



Industrial DC Motors

Among features of new line of dc motors are dynamic response, ability to take full load and overloads, to change speed rapidly, to maintain torque and tensions, and to reverse and stop quickly. Lower mechanical and electrical inertia have been combined to increase acceleration speed. Motors are available in sizes from 20 to 100 hp, with a wide range of mechanical enclosures for protection under various operating conditions. **Reliance Electric & Engineering Co.,** 1088 Ivanhoe Rd., Cleveland 10, O.

Circle No. **23** *on Reply Card*



Gear Driven Limit Switch

Designed for applications where critical control of limits is required, gear driven limit switch features limits which can be adjusted by means of two slotted screws. Adjustment is possible while equipment is in operation, with disengagement of gears unnecessary. Available for use with current capacities up to 550v, the new switches are easily wired and installed. Hardened steel drive shaft operates on precision bushings. Gears are machined to close tolerances and a minimum of lubrication is required. **Clark Door Co. Inc.,** 517 Hunterdon St., Newark 8, N. J.

Circle No. **24** *on Reply Card*

Decade Counter

Featuring printed circuits and a miniature high speed mechanical register combined with one electronic decade, new decade counter is capable of a sustained counting rate of 200 counts per second. Trigger level is 2.5v positive and is independent of pulse wave form or rise time. Pulses may originate from contact closure or from plug in photoelectric or magnetic pickups which are available as acces-

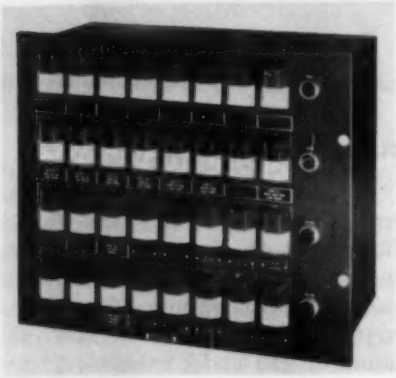
sory items. Count capacity of 1,000,000 makes the unit suitable for industrial and scientific counting applications. Pulse pair resolution is 5 microseconds; input impedance is 1 megohm. Counter weighs 7 lb. **Daytronic Corp.**, 216 S. Main St., Dayton 2, O.

Circle No. **25** *on Reply Card*

Machinery Mounts

Machinery mounts for isolating low speeds and high impact applications are designed for use where high absorption of vibration is necessary or where soft floors make control of vibration frequencies difficult. Available in five sizes, with 1, 2, 4, 6, or 9 springs, the mounts, depending on size, have an effective load range of from 250 to 6700 lb per mount. Since there is no need to bolt or shim when machines are mounted on spring mounts, machines can be installed and leveled within a matter of minutes. Each mount has a built in adjustment which permits leveling up to ¾-inch. Spring mount features adjustable damping. Damping adjustments can be made to prevent sudden spring recoil when a mount is subject to heavy impact and shock, and when mounted unit goes through resonance, thus checking excessive machine motion or bounce. Dampers are faced with friction brake linings, acting on the steel surfaces, which dampen horizontal as well as vertical forces. Mounts can be used on drop forge hammers, heavy stamping presses and hydraulic presses. **Barry Controls Inc.**, Watertown, Mass.

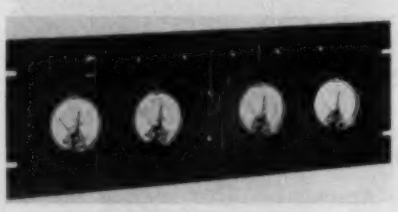
Circle No. **26** *on Reply Card*



Alarm System

New annunciator system performs a three-fold function. In addition to alerting any off normal condition in the manufacturing process by means of visual and audible alarm, it also gives an indication of the first failure in a sequential operation. Further, by means of an interlocking circuit, it automatically selects and monitors the correlated safety auxiliary shut down equipment. Standard unitized components are used throughout the entire system, with individual pluggable type hermetically sealed relay units for illuminating the two-color turret lenses and for performing all the functions of the system. **Industrial Automation Co.**, 2415 W. Montrose Ave., Chicago, Ill.

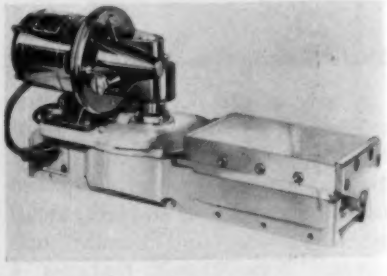
Circle No. **27** *on Reply Card*



Bearing Temperature Monitor

Internally shock mounted and sealed contact meter relays are the features of bearing temperature monitor. Monitor was originally developed for safety equipment in pipeline pumping stations to give immediate warning or shut down when a pump or motor bearing overheats. Each bearing or danger point has its own thermocouple and indicator which continuously shows the running temperature. Trip point is individually adjustable from the front of each meter relay. Any number of points can be monitored by a combination of panels, each of which is 7 by 19 inches, and holds one, two, three, or four meter relays. The range of each meter relay is normally 0 to 300F, but other ranges may be substituted. Each installation has a 50 amp circuit breaker for shut down, or if alarm is preferred, a plug-in series relay. Relay has snap action contacts rated 10 amp at 100v noninductive. An isolation transformer and full wave rectifier provide 20 ma at 115v dc for the relay or circuit breaker coil. Power input is 115 or 230v, 60 cycle. Monitor may be mounted on the machine or at a distance of a few hundred feet. In pipeline pumping stations, it is located with other controls in a separate building to avoid explosive fumes. Thermocouples may be grounded or insulated. **Assembly Products Inc.**, Chesterland, O.

Circle No. **28** *on Reply Card*

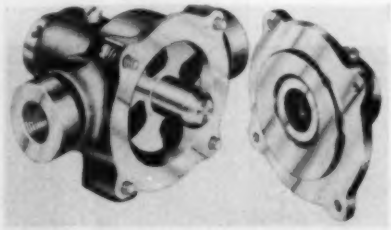


Power Feed Unit

Cam controlled automatic feed cycles for precision metalworking operations are provided by new cycling power feed unit. Self-contained mechanical unit consists of a slide assembly, feed mechanism, cam drive motor and housing. Equipment is designed for drilling, tapping, boring, reaming, sawing, milling, broaching and other precision work on parts of relatively

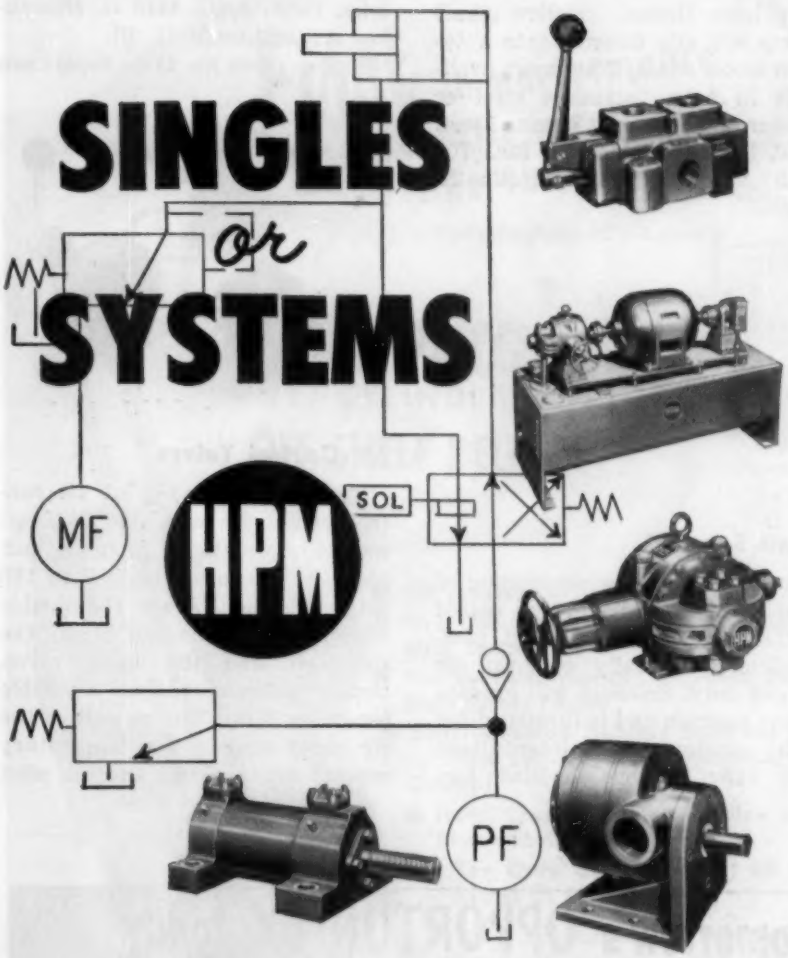
small size. Variation in feed cycles is possible through changing cams —an operation which can be completed in two or three minutes. Cycling power feed unit measures 17 inches long, 6 inches wide and 8⅛ inches high to the top of the motor housing. It can be mounted in a horizontal or vertical plane, or at an angle if desired. Slide assembly has a-working surface of 4 by 6 inches, and provides a maximum stroke of 2 inches. Gear motor rotates the cam which regulates the feed cycle of the slide, delivering a torque of 52 in.-lb. Standard cycle times of 4, 6, 8, 10, 12 and 16 seconds per revolution are available. **Russell T. Gilman Inc.,** 1243 Milton Ave., Janesville, Wis.

Circle No. **29** *on Reply Card*



Variable Cavity Pump

Maintaining a constant volume of flow despite fluctuations in city water pressure is a feature of variable cavity pump. When pressure in pump reaches a predetermined point, a spring loaded end plate moves outward, increasing the length of the pump cavity and enlarging the clearances between the ends of the rotor and the end plates. Increased clearances in the pump permit the liquid to recirculate, reducing the pump's maximum pressure. Pressures can be varied in this manner from 3 or 4 lb up to 75 lb. When pressures drop, the end plate is automatically forced in by springs to reduce clearances. Maximum expansion of the pump cavity at 75 lb pressure is 0.005-inch; maximum at 30 lb is 0.015-inch. The end plate serves as a relief valve without losing the pump's reversible rotation feature, also compensating for internal end wear. End plate operates like a piston, with the internal section being grooved and fitted with an O-ring seal to prevent leakage. Pump parts are



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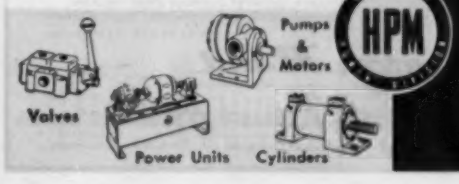
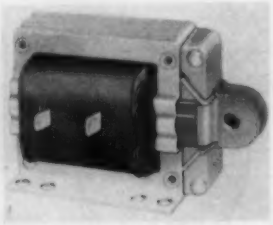


HYDRAULIC POWER DIVISION

available with either ⅜-inch internal pipe thread or external garden hose thread. Hollow shaft pump will slip directly onto a ½-inch motor shaft. Rollers are available in nylon, stainless steel or rubber; pump case is bronze. **Dept. K P, Hypro Engineering Inc.,** 700 39th Ave. N.E., Minneapolis 21, Minn.

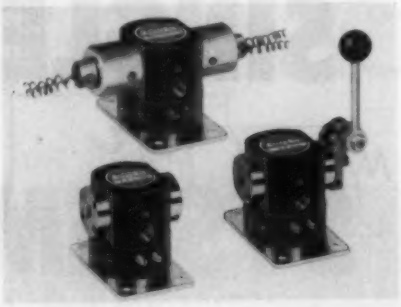
Circle No. **30** *on Reply Card*



Small Solenoid

Incorporating new positioning of double shading coil for high seated pull, solenoid is a lightweight, powerful unit especially designed for rugged duty. Solenoid will operate in any position and is furnished for both constant and intermittent duty, 115v, 60 cycle ac. Blade terminals are standard, with flexible leads optional. **Dormeyer Industries,** Dept. ANC, 3418 N. Milwaukee Ave., Chicago 41, Ill.

Circle No. **31** *on Reply Card*



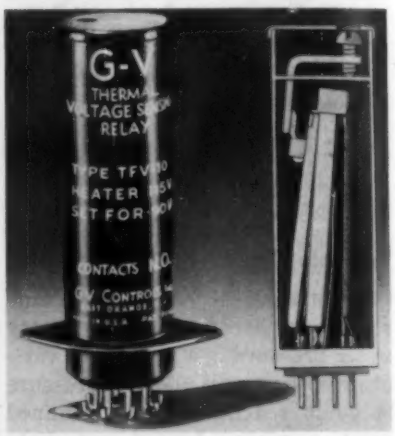
Air Control Valves

Twenty-four models of air control valves are available as four-way valves with ¼, ⅜ or ½-inch ports for operation from 5 to 150 psi. Key models are the double solenoid type, the air bleed, the air pilot and the hand valve. Double solenoid valves, available for either 8 or 110v, as well as the air bleed models, are momentary contact type. Hand and air pilot valves are offered either for double actuation or spring return. All valves feature two built-in speed controls and all friction surfaces are hardened and permanently coated with a baked on lubricant. Boxes and connectors are furnished with the solenoid valves and the coils are molded in epoxy resin. **A. K. Allen Co.,** 57 Meserole Ave., Brooklyn 22, N. Y.

Circle No. **32** *on Reply Card*

Thermal Type Sensing Relays

Current sensing and voltage sensing relays of the thermal type have applications in overload protection, over and under voltage alarm or cutoff, voltage regulation and battery charge control. Relays are hermetically sealed and their operating points are adjustable by means of a screw outside the sealed space. Thermal current and voltage sensing relays operate their contact circuits when current or voltage to their heaters exceeds the operating point for which the relay is set, and they release their contacts when the current or voltage drops below this value. Operating point is adjustable for each relay, over a 2 to 1 range. Nine different internal structures are available with time constants ranging from 1 second to 2½ minutes. Relays are made both in a plug-in form for 7-pin miniature tube sockets and in a flanged style with solder terminals. They operate interchangeably on dc or ac of any frequency. Relays are said to withstand vibration, shock and other environmental conditions required for military equipment.



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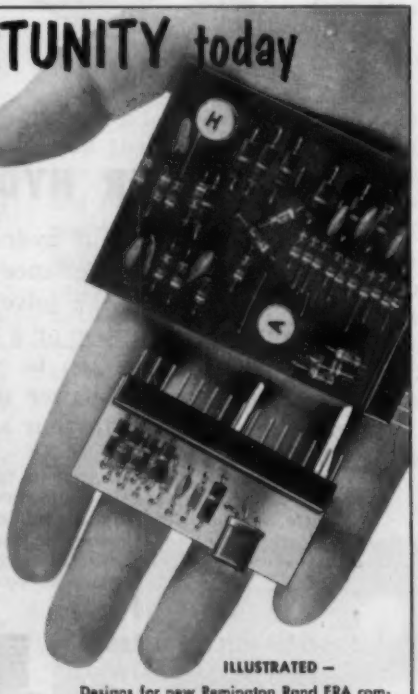

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Designs for new Remington Rand ERA computers that are now under development.
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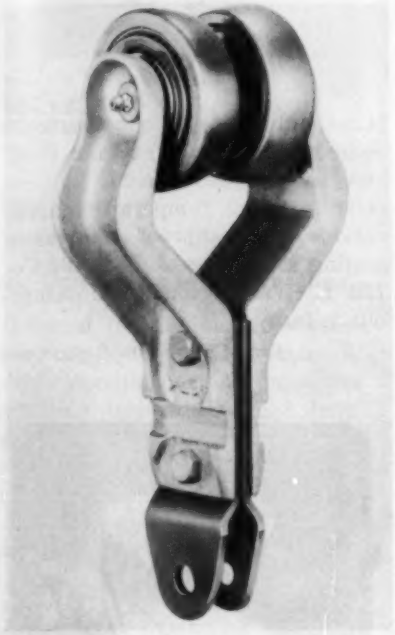
Weight is 1 to 1½ oz; diameter is ¾-inch, and length is 2⅜-inch. Contact rating is 3 amp at 115v ac noninductive load or at 28v dc noninductive. Relays are available for operating currents from 0.015 to 5 amp, and for voltages from 1 to 230. **G-V Controls Inc.**, 28 Hollywood Plaza, E. Orange, N. J.

Circle No. **33** *on Reply Card*



Overhead Conveyor Trolley

A new line of ball bearing trolleys for overhead conveyors is interchangeable with most other trolleys commonly used with rivetless conveyor chain. The bearings feature ball and cage assembly and concentrically ground raceways to keep friction at a minimum and assure rolling contact with the track at all positions. Wheels are steel with machined and hardened treads, and brackets are of forged steel. Labyrinth seals are standard, but special types can be provided for highly abrasive, dusty or dirty operations, as well as high temperature and other severe environmental conditions. Trolleys have a large lubricant storage space and a pressure type grease fitting. Sizes are available for 3, 4, or 6-inch I-beams and have the following rated load capacities in monoplane installations: 300 lb for the 3-inch I-beam, 600 lb for the 4-inch I-beam, and 1200 lb for the 6-inch I-beam. When used in multiplane installa-

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T-J Spacemaker CYLINDERS

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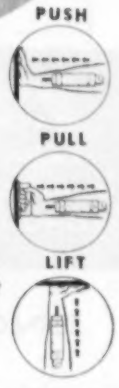

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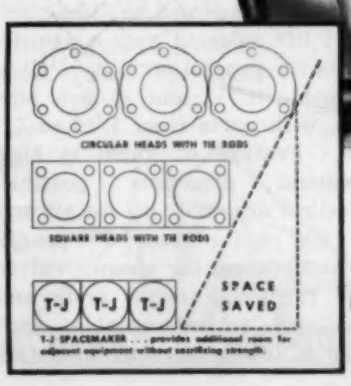
T-J Spacemaker Cylinders get first call for an ever-widening range of power movement jobs in industry today—because they're so advanced in design . . . so efficient and dependable in performance. Wide selection of styles and capacities. Check your needs now! Send for bulletin SM-454-2. The Tomkins-Johnson Co. Jackson, Mich.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T-J SPACEMAKER . . . provides additional room for adjacent equipment without sacrificing strength.

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Lock	Time
Brake	Blank
Press	Cut
Spin	Broach
Turn	Drill
Grind	Sequence
Weld	Close
Lower	Snub
Squeeze	Form
Bend	Pierce
Coin	Feed
Saw	Mill
Tap	Convey
Index	etc.
Braze	

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AUTOMATIC RADAR DATA PROCESSING, TRANSMISSION AND CORRELATION IN LARGE GROUND NETWORKS

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Digital computers similar to the successful Hughes airborne fire control computers are being applied by the Ground Systems Department to the information processing and computing functions of large ground radar weapons control systems.

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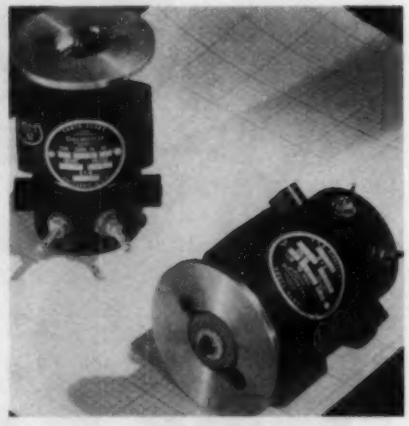
tions, load carrying capacities may be reduced due to reactions from the chain pull. Four-wheel trolleys are available when anticipated loads exceed the capacity of two-wheel trolleys. Two types of trolley are available, with bolted wheels and bracket assembly, or with permanent riveted assembly. **Link-Belt Co.**, 307 N. Michigan Ave., Chicago 1, Ill.

Circle No. **34** *on Reply Card*



Quick-Stopping DC Motor

Integral brake and permanent magnet motor are each actuated separately by 28v dc. Brake can bring armature to a stop within one shaft revolution when unit is operating at its rated speed of 4500 rpm. High starting torque is 50 oz-in. at 10 amp, and dynamic brake torque is 100 oz-in. minimum. Total input current, including a 0.25 amp brake current, is 2.5 amp with a 40 w load. Motor is designed for continuous duty applications, has reversible rotation. **Dalmotor Co.**, 1304 Clay St., Santa Clara, Calif.

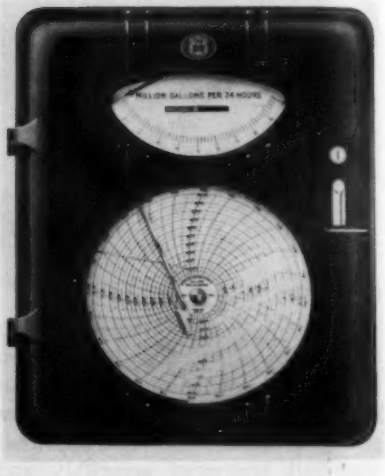
Circle No. **35** *on Reply Card*

Direct Lift Solenoid Valves

Made in brass and stainless steel, direct lift solenoid valves are designed for general service. Valves are made in ⅛ and ¼-inch pipe sizes, with ports from 1/16 to ¼-inch. Feature of valve is high maximum pressures possible. Pressures are: 1000 psi for air and gas; 600 psi for water; 500 psi for oil, and 200 psi for steam. Valves have renewable metal seats and coils are interchangeable with those of other company manufac-

tured valves. Special assemblies available on both brass and stainless steel types include silicone coils for high temperature applications and leakproof and guidon seating assemblies. **J. D. Gould Co.**, 730 E. Washington St., Indianapolis 2, Ind.

Circle No. **36** *on Reply Card*

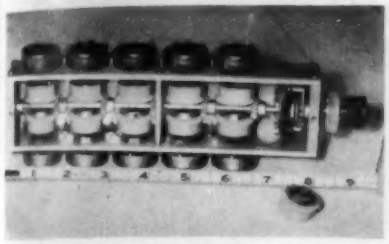


Electric Transmission System

Called Orthoflow, electric transmission system uses a two-wire circuit. It is designed for installation where accurate transmission of flow or other measurable data is required over distances and it is not possible to obtain data through the use of mechanical measuring devices. It can be adapted to transmit data over private wires in in-plant services, or, with the addition of a few parts, for use over leased telephone channels where transmission of data over many miles may be accomplished. System can be used for the transmission of flow, liquid level or pressure measurement.

Transmitting units may be applied to mercury cylinders of varying sizes to produce measurements over 4 to 1, 10 to 1, 13 to 1, 18.5 to 1 and 20 to 1 ratios with accuracy errors not exceeding ±2 per cent at any point. **Simplex Valve & Meter Co.**, 7 E. Orange St., Lancaster, Pa.

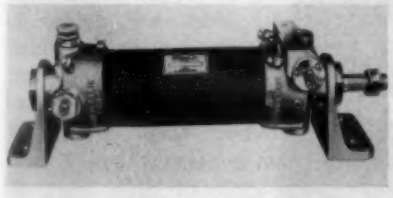
Circle No. **37** *on Reply Card*



Gear Drive Magnetic Clutches

Designed for use on differential drives, computers, guided missiles, multiple servo drives, and multiple positioning units, these gear drive magnetic clutches are available in three models. Two of these are for continuous rotation; the other is for a single turn adjustment. Models operate at voltages from 6 to 30 dc or rectified ac, with under 1 w power consumption. Clutches transmit from less than 1 oz-inch to over 15 oz-inches. Units have zero clutch slip when operated within rated conditions. **Electronic Mfg. Engineers Co.**, 2410 Beacon Ave., Seattle 44, Wash.

Circle No. **38** *on Reply Card*



Air-Hydraulic Cylinder

Developed to provide control of hydraulic power from any shop air supply, air hydraulic cylinder is of coaxial design. Air cylinder surrounds oil cylinder in coaxial unit, avoiding excessive length. Expanding exhaust air aids in cooling oil to assure dependable operation under continuous rapid cycling and heavy loads. Automatic models with built in control of speed and

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POCKETSCOPE
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MODEL S-14-A

DC COUPLED
10 mv/inch
½ CYCLE SWEEP

Size: 12" x 6" x 7"
12¾ Pounds

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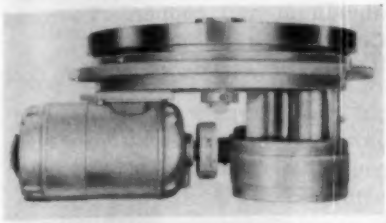
direction, adjustable fast traverse in either direction, and automatic recycling are available. Standard models are remotely controlled with valving and piping. Unit develops hydraulic piston thrust of 3.14 x airline pressure, and pull of 2.7 x airline pressure. Cylinder is available in stroke lengths up to 72 inches. **Modernair Corp.**, 400 Preda St., San Leandro, Calif.

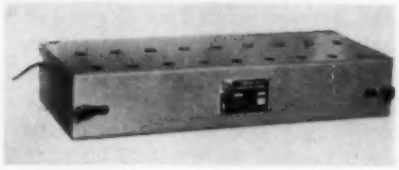
Circle No. **39** *on Reply Card*



Powered Index Tables

Power driven automatic index table is available in 21 and 34-inch diameters with 6, 8, or 12 stations. Tables are operated by a Geneva drive, using a needle bearing cam follower operating in ways faced with hardened and ground tool steel wearing plates. Steel lock pin, actuated by a cam plate, enters the ways before the cam follower leaves them so that, at no time in the operation of the table, can it be free wheeled. Lock pin projects through the under side of the table housing and its up and down movement opens and closes an off and on limit switch which controls the current supply to the machine on which the table is installed. Table is driven by a 220 to 440v, three-phase, 60 cycle 1800 rpm brake motor through a bronze worm and gear reduction unit. Models are furnished with tables equipped with locators for interchangeable top plates, and can be furnished with an adaptor which permits horizontal mounting for use as the drive for an indexing drum. The 21-inch model is driven by a ¾-hp motor and has a load capacity of 400 lb with an indexing cycle of 1.5 seconds under normal operating conditions. The 34-inch table, driven by a 1-hp motor will carry an 800 lb load with an indexing cycle of 2 seconds under normal operating conditions. **Cleveland Tapping Machine Co.**, Canton, O.

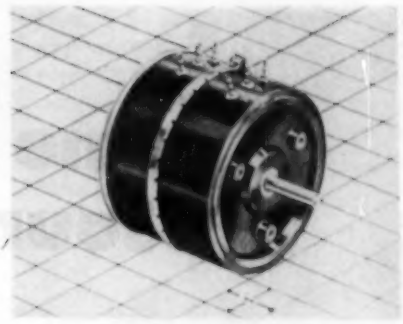
Circle No. **40** *on Reply Card*



Data Transmission Terminal

Audio frequency shift terminal is designed for use in the transmission and frequency multiplexing of telemetering, supervisory control and telegraph signals. Equipment is relatively insensitive to noise and amplitude variations of the communication link and is directly applicable to both frequency and time duration type telemetering systems. When used in conjunction with telephone dials, stepping switches or relay pyramids, it is suited for supervisory or remote control functions. A mark-hold circuit is provided for party line on-off keying, line failure indication and teletypewriter hold-in under no signal conditions. Equipment may be applied to a single telephone line, microwave or carrier channel for transmission to a remote point. In the voice frequency band, 23 channels from 300 to 3200 cps are available for telemetering and supervisory control. Special filters are available in the voice band from 765 to 3100 cps which will provide 14 channels of telegraph at printing speeds of 100 words per minute. When used in conjunction with microwave or carrier systems, the number of channels may be extended to at least 40 for telegraph and to 50 channels for supervisory control and telemetering. Equipment is available as a single transmitter or receiver, dual transmitter or dual receiver, or transmitter receiver for half or full duplex operation. Complete terminal measures 3½ by 19 by 8 inches for mounting in a standard relay rack, and includes equipment and loop power supplies, a voltage stabilized frequency shift tone oscillator, 20 db transmitter filter, 20 db receiving filter, limiting amplifiers, discriminator, output keying circuit, transmitter output, receiver input and bias controls. **Radio Frequency Laboratories Inc.**, Powerville Rd., Boonton, N. J.

Circle No. **41** *on Reply Card*



Precision Potentiometers

Designed for automation and industrial applications, precision potentiometers are available in single or ganged assemblies in three sizes, P3, P1-⅝ and P1-¼. Mounting by means of threaded bushing is standard on P1-¼ and P1-⅝. Precision pilot is optional for servo applications. P3 mounting consists of three tapped holes. Potentiometers feature accuracy, low noise, long life, low torque, minimized distributed capacity, good frequency response and high stability. **Technology Instrument Corp.**, Acton, Mass.

Circle No. **42** *on Reply Card*

Leakproof Fasteners

Leakproof fastener with a one-piece metal head and preassembled neoprene washer is designed for fast, trouble free assembly. Neoprene washer retards electrolysis between dissimilar metals by insulating against direct contact such as a steel fastener in aluminum. Fasteners are well suited for industries where electrolysis, heat or electrical contact pose problems. Fasteners are said to prevent leaks, protect surfaces, absorb shocks and stop squeaks. Neoprene washer flows under pressure to conform with

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with years of experience,
proven ability
and adequate facilities
to handle your
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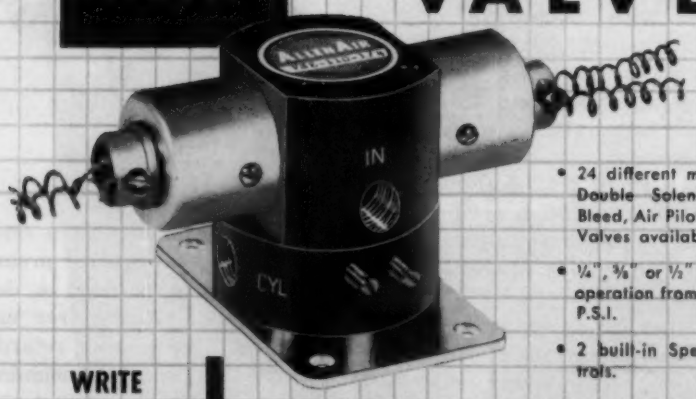
ALLENAIR
4-WAY
VALVES



- 24 different models of Double Solenoid, Air Bleed, Air Pilot & Hand Valves available.
- ¼", ⅜" or ½" Ports for operation from 5 to 150 P.S.I.
- 2 built-in Speed Controls.

WRITE FOR ILLUSTRATED CATALOGS

ALLENAIR—manufacturers of Dial Feed Tables, Valves, Clamps & Cylinders (plain or with built-in valves. Up to 20" of stroke in stock.)

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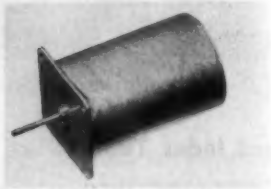
The A. K. ALLEN CO.
57 MESEROLE AVENUE • BROOKLYN 22, NEW YORK

contour of concave and convex surfaces to provide a seal that is both air tight and water tight. Special undercut in one-piece metal head and washer traps and controls flow of the neoprene when the fastener is tightened. Neoprene washers are preassembled with self-tapping screws, stove bolts, machine screws, wood screws, nails and special products. Fasteners are available in stainless, carbon and alloy steels, as well as nonferrous metals such as aluminum and copper. **Townsend Co.**, New Brighton, Pa.

Circle No. **43** *on Reply Card*



Displacement Transducer

Linear displacement transducer is a variable reluctance pickup for converting linear motion into an electric output. Unit is designed to be free from changes in scale factor with variations in frequency, excitation voltage and temperature over wide ranges of these parameters. Transducer consists of two coils in a magnetic circuit whose configuration allows an armature shaft to vary the inductance of the two coils when displaced. Relative shift of inductance is shown through a simple bridge circuit as an output voltage which in many applications proves high enough to preclude intermediate amplification. Amplitude of output voltage is a function of input voltage; input voltage ranges from 28 to 115 v. Unit is designed toward industrial automation, monitoring, electronic gaging and control system sensing. It consists of a sensing element, bridge circuitry, mounting flanges or holes, and a female connector or a pigtail cable assembly with termination in a connector. Transducer is designed for military applications in pressure transducers, accelerometers and control system sensors. **General Cybernetics Corp.**, P. O. Box 987, Beverly Hills, Calif.

Circle No. **44** *on Reply Card*

Controlled Volume Pump

Engineered for control of fluid flow at pressures ranging from 7500 to 50,000 psi, controlled volume pump is designed for high pressure synthesis, hydrostatic pressure testing and high pressure fluid metering. Seven different units are offered to cover the range 7500 to 50,000 psi. Maximum capacity at 50,000 psi is 12.5 gal per hour; at 7500 psi, 94 gal per hour. Materials of construction below 25,000 psi are 300-series stainless steel with 400-series trim. Above 25,000 psi, materials are Ni-Cr-Mo steel with tungsten carbide trim. High volumetric efficiency is said to be assured, since complete scavenging of the liquid end displacement chamber is provided at all plunger stroke length settings. **Milton Roy Co.**, Station D, 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Circle No. **45** *on Reply Card*

Miniature Drive Motor

Designed as a drive motor for switches, cams, servos and similar applications, permanent magnet dc motor is 1⅛-inch diameter, weighs only 5½ oz. Unit may be designed for any input voltage from 6 to 30v dc, and geared for any output speed from 4 to 10 rpm. Miniature motor has an aluminum alloy case with plastic molded brush housing, and permanently sealed and greased ball bearings. **El Ray Motor Co.**, N. Hollywood, Calif.

Circle No. **46** *on Reply Card*

Time Delay Relay

Silicone controlled time delay relay is available with standard timings from ¼ to 120 seconds. Variable flux operation, caused by the

changing relationship of a solenoid coil and its core, produces definitive contact action. In the new design, magneto-motive force has been increased. This factor com-

Another
FEEDALL Automation Unit
ELEVATING MAGAZINE LOADER!

● This Air Index Conveyor carries bars to a higher delivery point. The Model illustrated is for short bars up to 6″ long. It has a variable delivery rate of 1 to 12 per minute. Specifications can be varied somewhat to suit individual requirements.

Consult FEEDALL about your Automatic Feeder Needs. FEEDALL Units are available with Blade, Hopper, Rotary or Vibratory Feeds.

Why not let our engineers give you the benefit of their experience in solving your feeder problems. Write today.

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WILLOUGHBY, OHIO, U. S. A.

bined with special spring loading of the armature has achieved high speed contact action with substantial pressure for reducing contact resistance. Relay uses hydraulic-magnetic principle, in which a silicone fluid is the basis of time delay. A movable iron core, hermetically sealed in a nonmagnetic metal tube extending through a solenoid coil, is drawn into the magnetic field resulting when the coil is energized. The silicone fluid slows the rate of core travel, thus controlling the response time. Contacts are actuated as the core touches the pole piece and check valve construction within the core allows faster resetting of the relay. Time delay relays are furnished with coil ratings from 24 to 240v ac; 6 to 125v dc. **Heinemann Electric Co.**, 261 Plum St., Trenton 2, N. J.

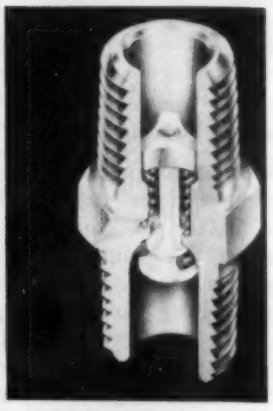
Circle No. **47** *on Reply Card*

Thermocouple Air Converter

Designed for use with thermocouples or other low voltage dc inputs, thermocouple air converter

has two main sections. Upper section is an amplifier-converter; lower section is an electropneumatic transducer of the null-balance type in which a magnetic force is balanced against the force produced by an air output pressure from a pneumatic pilot. Used to convert dc millivolt input signals to an air loading pressure of 3-15 psi in a linear relationship and enable users to retain pneumatic recording and controlling panel equipment for use with components of electronic process control systems. Temperature range is −50C to 3000F. Unit contains no batteries, slide wires or motors. **Swartwout Co.**, 18511 Euclid Ave., Cleveland 12, O.

Circle No. **48** *on Reply Card*



Check Valve

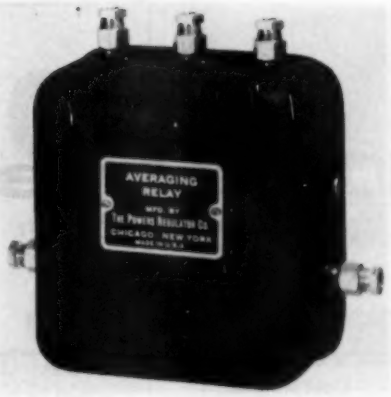
Designed for the 0 to 10,000 psi range, check valve has floating poppet design which is not affected by foreign particles in the fluid and eliminates "wire drawing"

The CHIP-TOTE conveyor permits complete utilization of machine tools by eliminating shut-down for manual scrap removal.

It handles a continuous flow of hot, wet or dry chips, turnings and borings from any multiple spindle automatic machine.

across the seat. Spherical metal seat gives support for the O-ring which serves as a sealing member and absorbs the closing shock. Check valve is suitable for most high pressure hydraulic or pneumatic applications. It is of one-piece body construction, and is available in several body and O-ring materials combinations. **James-Pond-Clark,** 2181 E. Foothill Blvd., Pasadena 8, Calif.

Circle No. **49** *on Reply Card*



Pneumatic Relays

Among functions performed by pneumatic air relays are air volume amplifying; pressure reversing, retarding, advancing and averaging; differential controlling; and minimum pressure controlling. Models in line provide different types of air volume and pressure control. One device allows the highest of two varying air supply pressures to determine the control pressure. Another acts as a check valve, permitting air flow in one direction only. An electro-pneumatic valve allows air passage only when the solenoid is energized. Direct or reverse action is optional on many of the models. Most of the relays have ⅛-inch NPT connections for air pressures up to approximately 25 psi. **Powers Regulator Co.,** Dept. ANC, Skokie, Ill.

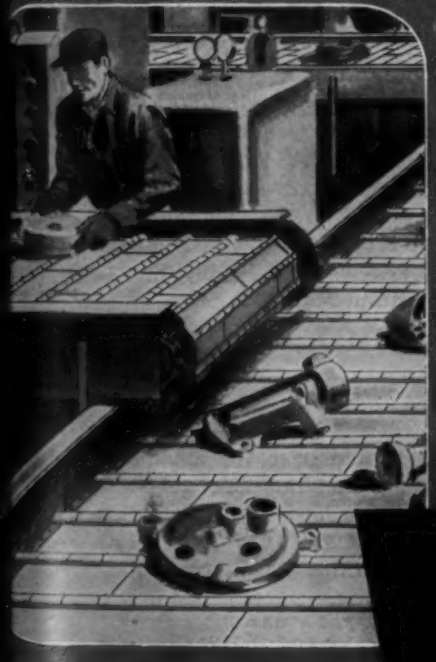
Circle No. **50** *on Reply Card*

Stainless Steel Valve

Control of gases and liquids normally corrosive to bronze, steel, or iron is provided by a new, stainless steel, solenoid operated, 2-way valve. Valves are normally closed, operate at a frequency of 400 times per minute and at pressures up to 250 psi. Floating core construction eliminates chatter. All internal parts are accessible without removing valve body from pipe line. Removal of valve bonnet permits sterilizing and cleaning. Standard coils are suitable for

temperatures up to 212F, but coils can be supplied for temperatures to 450F. **Automatic Switch Co.,** 391 Lakeside Ave., Orange, N. J.

Circle No. **51** *on Reply Card*



Now is the time to put AUTOMATION to work . . . Now is the time to cut production costs . . . May-Fran engineers design and build complete scrap handling systems for the automatic removal of machine turnings or chips. May-Fran conveyors will transmit scrap to ultimate point of disposal.

Press Scrap systems can be made completely automatic. Hinged-steel belt will take scrap from presses, handle it through blanking, shearing, forming and baling processes, and deliver it to rail cars.

May-Fran is prepared to engineer, fabricate and install complete conveyor systems to your specifications.

Write today for complete information on how an automatic scrap removal system will cut your production costs.

Bulletin MF-530 describes the new Hinged-Steel conveyor belt.

Bulletin MF-640 describes the Chip-Tote conveyor which removes scrap from operating machines.

DESIGNERS AND ENGINEERS OF COMPLETE SCRAP HANDLING SYSTEMS

MAY-FRAN ENGINEERING, INC.

Hinged-steel belting handles scrap as well as hot heavy and abrasive castings. Belt is economical . . . maintenance-free.

5865-MF

1761 CLARKSTONE ROAD
CLEVELAND 14, OHIO

AUTOMATION patents

Copies of patents are available at 25 cents each from the Commissioner of Patents, Washington 25, D. C.

Components

MECHANISM FOR CONVERTING RECIPROCATING INTO ROTARY MOTION AND VICE VERSA

Motion of reciprocating elements may be converted to rotary motion of a shaft whose axis is parallel to the reciprocating elements, and vice versa. Reciprocating elements linked to a swivel member riding on a spheroidal bearing move or are moved by a crankshaft. Patent 2,702,483 by Marius G. H. Girodin.

• • •

Controls

MOISTURE CONTROL

Device measures by electrical means the moisture content of textile material being conveyed and controls the rate of travel through a drying zone. Patent 2,702,948 by John S. Seney, assigned to E. I. du Pont de Nemours & Co.

• • •

Handling

LAUNDRY SHAKE-OUT DEVICE

Laundry carried on a conveyor is shaken out by action of rotors between short conveyors. Laundry dumped into path of rotor arms is flung into the air and falls on next conveyor. Patent 2,677,900 by Frederick A. Mann Jr.

MULTIPLE PREDETERMINED QUANTITY SELECTOR FOR ARTICLE DISPENSING SYSTEMS

System for dispensing variety of articles in preselected quantities through electrically actuated releasing devices controlled by electrical counting means and a quantity selection means. Patent 2,679,354 by Thomas S. Skillman, assigned to Punch Engineering Pty Ltd., Cammeray, Australia.

SELECTIVE TRANSPORT MECHANISM

Equipment for conveying meals on carriers from a kitchen to any preselected one of several receiving stations. Combination of low speed conveyor from kitchen, accelerating means, high speed conveyor to vicinity of destination, deflectors selectively operated in response to identification means on the carriers to deflect carriers to low speed conveyors delivering to receiving stations. Patent 2,679,920 by Arthur H. V. Steele, assigned to J. Lyons & Co. Ltd., London, England.

Machine Tools

MECHANISM FOR ROTATING WORKPIECES RELATIVE TO MACHINE TOOLS, INCLUDING STRESS RELIEF MEANS

Workpiece in machine tool is supported and rotated by synchronously driven spindles at both ends of piece. Spindle clamping means on one spindle may be selectively closed or opened and engaged or disengaged from driving connection during rotation of the spindles to relieve stress on the workpiece. Patent 2,702,495 by John O. Creek, assigned to A. V. Roe Canada Ltd., Malton, Canada.

• • •

Process Design

METHOD OF AND APPARATUS FOR FILLING CANS TO A UNIFORM LIQUID LEVEL

Containers are filled with liquid to a desired level by initially underfilling then delivering to each container a supplemental amount of liquid more than sufficient to fill it and simultaneously withdrawing excess liquid at the desired level. Patent 2,700,495 by Samuel S. Jacobs, assigned to American Can Co.

APPARATUS FOR STRETCHING SHEET MATERIAL

Material which can be stretched when heated is positively fed at a controlled speed over a heating surface. Continuous clamping means with diverging paths stretch the film laterally and controlled output speed greater than the input speed imparts longitudinal stretch. Patent 2,702,406 by Exa G. Reed, assigned to Energized Materials Corp.

• • •

Testing

VISCOSIMETER

Fluid viscosity is indicated from the amount of power transmitted by a coupling mechanism to maintain a constant rotation speed of a rotor immersed in the fluid. Patent 2,679,157 by Paul G. Carpenter, assigned to Phillips Petroleum Co.

GAGING AND DETECTING APPARATUS

Surface flaws in a sealing surface of a glass container are automatically detected. Presence of a flaw is indicated by reflection of a light beam to a photoelectric cell. Patent 2,682,802 by William J. Fedorchak, Verney G. Politsch, Luther H. Wideman, and Donald M. Duncan, assigned to Owens-Illinois Glass Co.

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Produced economically in our modern plant for:

AUTOMOTIVE, INDUSTRIAL EQUIPMENT, DOMESTIC APPLIANCE, AGRICULTURAL INDUSTRIES AND OTHERS; will boost your output at material savings.

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I NEW GAST Model 0211 AIR PUMP weighs ⅓ less — is a truly

COMPACT COMPONENT

This *new* Gast rotary-vane Air Pump offers many advantages, including: ⅓ less weight — (now 22 lbs.) — with more compact, streamlined design. Rotor mounted on new G. E. Form "G" motor shaft. Vanes give positive, pulseless air delivery. Rubber-cradled mounting dampens vibration, increases quiet.

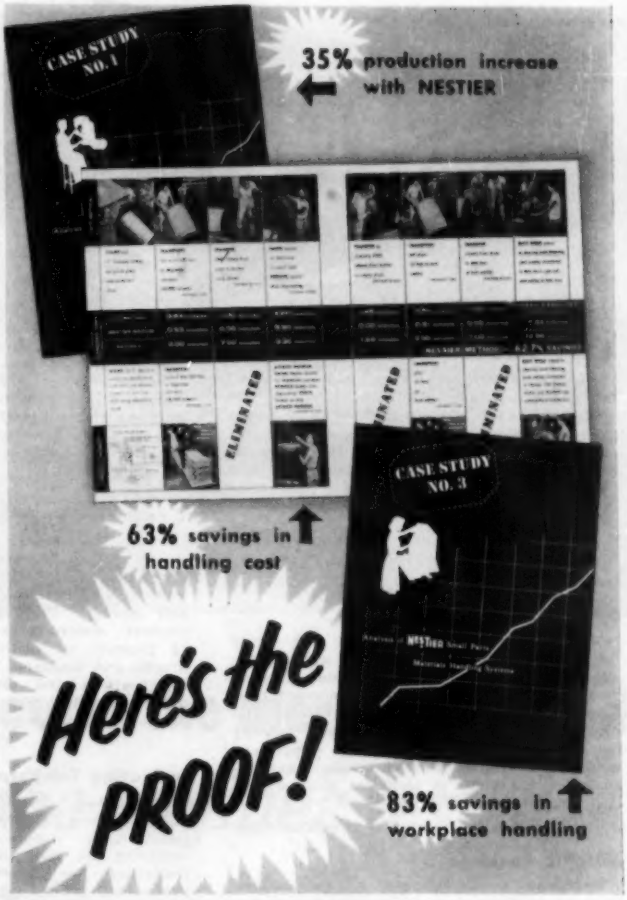
Model 0211 produces up to 25 p.s.i. or 27" vac., or 1.3 c.f.m. running open. ⅛ h.p. motor uses only 3.8 amps. Ideal for automatic machines, industrial instruments and controls. Present uses: paper feeding in packaging, printing frames, or as portable laboratory air source.

Let *your* product benefit from this compact component — *write for Bulletin 1254 and "Application Ideas" Booklet!* Gast Manufacturing Corp., P.O. Box 117-E Benton Harbor, Michigan.

Original Equipment Manufacturers for Over 25 Years

GAST ROTARY
- AIR MOTORS TO 4 H.P.
- COMPRESSORS TO 30 P.S.I.
- VACUUM PUMPS TO 28 IN.

See Our Catalog in Sweet's Product Design File



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NESTIER BOXES AND BASKETS

NESTIER HOPPER RACK ASSEMBLIES

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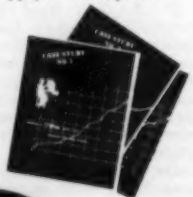

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new CATALOGS AND LITERATURE

In-Line Machines

Mercury Engineering Corp.—Among in-line machines discussed in six-page bulletin are double roll stand, prefeed unit, printing press, single or double pass drier, constant tension unit, two or three-ply laminating unit, cutting and creasing press and stripping and delivery unit. Dimensioned sketch illustrates position of these machines in a production line, and a discussion of their features and applications is included. Photograph of in-line folding carton equipment is also given.

Circle No. 52 on Reply Card

Solenoid Pilot Valves

Valvair Corp.—Line of solenoid pilot valves for air, vacuum, oil, and water with soluble oil is discussed in eight-page folder. Among models illustrated are three-way solenoid pilot valves, two-way solenoid pilot valves, and four-way double solenoid pilot valves. Cutaway illustrations show components of valves and specification charts for all models are included. Also given is technical data on operation of solenoid pilot valves.

Circle No. 53 on Reply Card

Metallic Packings

Hydraulic Accessories Co. — Twelve-page brochure is devoted to discussion of metallic packings. Among types discussed are rod and piston packings, piston rings, rod wipers and cartridge packings. Designed for use on pneumatic or hydraulic cylinders, these metallic packings are composed of pairs of stiff metallic sealing rings, enveloped by pliable elastic cushion rings. Brochure gives dimensions and specifications of various models; ordering information is also included.

Circle No. 54 on Reply Card

Adjustable Speed Drives

Machinery Electrification Inc. — Adjustable speed drives and load controls are discussed in 10-page brochures. Photographs and dimensioned sketches illustrate electronic control units, and push button stations. Price lists, application and operation data, special features of adjustable speed drives and load controls, installation information, and diagrams showing replacement parts are included in brochures.

Circle No. 55 on Reply Card

Multiple Spindle Heads

U. S. Drill Head Co.—Twenty-eight page brochure describes line of multiple spindle heads designed for drilling, reaming, tapping and boring. Among models covered are fixed center multiple spindle drill heads, adjustable multiple spindle drill heads, and individual lead screw tapping heads. Photographs and cross-section views of various models are given. Also illustrated and described are fixtures, bushing plates, drill heads, adapter assemblies, drill chucks, tap chucks and tap holders.

Circle No. 56 on Reply Card

Digital Converter Catalog

Fischer & Porter Co.—Line of digital converters, electromechanical shaft position types and voltage types, are described in a 12-page catalog. First type mechanically converts shaft position into discreet electrical contact combinations for a digital code, permitting automatic logging or input to computers for industrial operations. Second type converts voltages to digits for spans of 0 to 1 millivolt and up. Various models of both types are described for dynamic readout, linear or non-linear conversion and direct reading ranges. Operation, characteristics, accuracy and specifications of the digital converters are described and illustrated with photographs, drawings and installation diagrams.

Circle No. 57 on Reply Card

Continuous Level Indicator

Fielden Instrument Div., Robertshaw-Fulton Controls Co.—Eight-page brochure describes continuous level indicator, Telstor, for use with liquids, granular solids, viscous fluids and powder. Unit is used on tanks, bins, hoppers, reservoirs or other vessels subjected to pressure or vacuum. Installation photographs and diagrams are included, along with specifications and dimensions. Principle of operation of the Telstor and ordering information are also given.

Circle No. 58 on Reply Card

Indicating Temperature Controller

Fenwal Inc.—Performance specifications, applications and a complete description of a liquid filled, remote indicating temperature controller are given in a two-page brochure. Controller has applications in processing equipment, kilns, ovens, packaging machinery, liquid baths and melting pots. Brochure includes photographs of the controller, and a diagram illustrating its dimensions.

Circle No. 59 on Reply Card

Miniature Connectors

DeJUR-Amsco Corp.—Miniature connectors with one-piece molded inserts are the subject of a four-page brochure. Actual size illustrations of the assembled connector with cable clamp are given. Components shown in actual size are the box shell, receptacle insert and coupling shell; plug insert, coupling ring and cable clamp adapter. Electrical and mechanical specifications, and drawings illustrating the mounting and clearance dimensions of the connectors are included in the brochure.

Circle No. 60 on Reply Card

Electric Circuit Control Regulator

Electric Regulator Corp.—Eight-page bulletin describes a direct action, finger type electric circuit control regulator. Unit is used to regulate voltage by direct control of the main fields of large alternators and generators. Bulletin includes photographs of the regulator, lists of the basic types and their modifications, diagrams illustrating sensing circuits, data on operating coils, and outline drawings showing typical applications of the regulator as a dc line-load regulator, a self-excited generator, an ac line-load regulator and a self-excited alternator.

Circle No. 61 on Reply Card

Telemetering System

Control Corp.—System designed to telemeter all electrical values and by means of mechanical equipment to telemeter other values such as pressure, flow, regulator position, etc., is discussed in eight-page brochure. Telemetering is used in indicating instruments and recorders found on electric utility systems, pipelines and waterworks systems, and other applications. Discussion of how different areas find uses for telemetering systems is included. Brochure contains photographs and sketch of system.

Circle No. 62 on Reply Card

Detector Systems

W. F. & John Barnes Co.—Detector systems designed to locate malfunctioning components and failures in any complex electrical control setup are discussed in an eight-page brochure. Wired-in checking system consists of separate electrical circuits wired to schematic electrical diagrams. Photographs illustrate applications of detector systems, and other company designed equipment. Brochure also includes general specifications of the detector system and a typical test procedure for locating failures.

Circle No. 63 on Reply Card

Electrical Conduit Booklet

National Electric Products Corp. — Heavy duty steel electrical conduit is the subject of a new booklet. Test data sheets are used to illustrate how the conduit withstands corrosive attacks of salt spray, sulfuric acid, caustic soda and exposure to excessive heat. Conduit is designed for installations in industrial, chemical, pickling and plating plants, rayon and textile mills, paper mills, mines, refineries, railroads, warehouses, docks and piers, and packing houses. Brochure includes photographs which illustrate condition of the conduit after exposure to corrosive attacks.

Circle No. 64 on Reply Card

Telephone Relays

Automatic Electric Sales Corp.—Catalog supplement discusses new applications of telephone relays and switches in automation of machine tools. The sheet describes and diagrams the function of rotary stepping switches in controlling two machines manufactured by Avey Drilling Machine Co. Photographs of machines in which relays are used are included in the two-page supplement.

Circle No. 65 on Reply Card

Magnetic Tape Recording

Ampex Corp.— Sixteen-page bulletin discusses magnetic tape recording. Some applications of tape fed information are with oscilloscopes, galvanometers, oscillographs, pen recorders, computers, automatic data reducers, card punch machines and process controls. Bulletin contains section on operation of magnetic tape recorder and data on its performance. Sketches illustrate magnetic tape applications in flight testing, shock and vibration recording, machine and process control, geophysical exploration, wave analysis, computing devices, study of sounds, medical teaching and research, facsimile recording and uniform re-creation of phenomena. Photographs of several models and their accessories are also given.

Circle No. 66 on Reply Card

Instruments and Equipment Catalog

Minneapolis - Honeywell Regulator Co. — Twenty-six page catalog contains description of main types of company industrial instruments and equipment, with references to more detailed literature on each type. Among the products discussed are millivoltmeter pyrometers, potentiometers, null indicators, temperature detectors, thermometers, pressure gages, flow and liquid level meters, pneumatic units, systems and components, panelboards, valves, diaphragm motors, switches, starters, contactors, relays, dampers and damper operators. Photographs of items discussed are included. Additional index by variables assists the reader in locating desired instrument.

Circle No. 67 on Reply Card

Feeders and Rotary Valves

Fuller Co.—Eight-page bulletin describes line of roll and vane type feeders and rotary valves. Feeders, built of cast iron or iron and steel combinations, are designed to handle a variety of dry pulverized and granular materials. Bulletin includes descriptions of various types of feeders and lists materials handled by them, such as chemicals, powdered metals, grains and food products, rubber, bone and wood products. Photographs and drawings of different types of feeders, accompanied by tables giving dimension and capacity figures, are included.

Circle No. 81 on Reply Card

Telemetering Components

Hays Corp.—Twelve-page brochure describes telemetering components, features and applications. Transmitters, electric transmission system, receivers, integrators, indicators, and recorders are illustrated and discussed. Schematic drawings are used, and photographs of models of indicators, recorders, integrators, calibration check tubes and explosion and weatherproof housings are given.

Circle No. 82 on Reply Card

Door Operator

National Pneumatic Co. Inc. & Holtzer-Cabot Divs.—Door operator, called Economatic, is the subject of a four-page brochure. Economatic is designed for factories, restaurants, supermarkets, banks, hospitals, hotels, office buildings and theaters. Automatic controls available include treadle and photoelectric units. With treadle control, door is operated by stepping on a carpet which may be positioned on either side of the doorway or may extend through the doorway. With photoelectric control, door opens automatically when the entrance light beam is interrupted, and automatically closes after a predetermined interval. Photographs illustrate typical installations of door operator and diagrams illustrate different types of control.

Circle No. 83 on Reply Card

Die Casting Machine

American Die Casting Machinery Co.—Four-page brochure discusses die casting machines which will make up to 700 shots per hour to produce castings weighing 1 oz to 2½ lb. Photographs of four models are included in the brochure. Also given are specifications of six different models, and illustrations of their component parts. Machines are available in air or hydraulically operated plunger; goose neck type for zinc, tin and lead, or cold chamber type for aluminum, brass and magnesium.

Circle No. 84 on Reply Card

High Frequency and Voltage Equipment

Scientific Electric Co. — Line of electronic equipment is discussed in eight-page brochure. Equipment illustrated includes high frequency dielectric plastic heat sealing units, test units, induction heaters, spot welders and high voltage power supplies. Application photographs show electronic equipment: setup for induction soldering battery cable lugs, with belt conveyor using dielectric heating units, in automatic fixture for induction soldering loudspeaker magnets to frames, for preheating cathode ray tubes, in automatic soldering of cigarette lighters, and for 24-position plastic high frequency belt sealer.

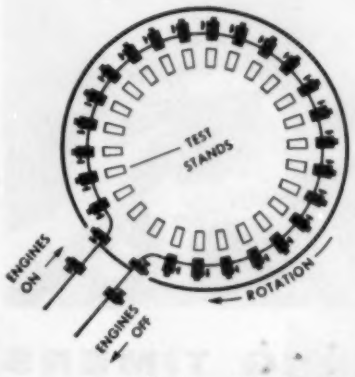
Circle No. 85 on Reply Card

Power Unit Brochure

Pantex Mfg. Corp. — Sixteen-page bulletin gives application, specification, price and operating data on Hydro-Air power unit, a piston type device which combines long stroke and fast action of pneumatic cylinder with positive action and force multiplication of hydraulic cylinder into a single package. Designed for closing presses, actuating heavy machinery or exerting thrust forces, power unit is operated entirely by compressed air. Bulletin includes drawings, photographs, and a table to describe the unit, its operations, engineering specifications and capacities and its applications.

Circle No. 86 on Reply Card

Once around the merry-go-round
and the engine's tested!



The run-in test is no bottleneck in this automatic production line. In this great new engine plant in the Detroit area, engines are tested as they move along the main stream of production.

The testing merry-go-round, 50 feet in diameter, carries 26 test stations. Hooked to gas, water, instruments and gauges, the engine gets its complete test in one revolution, timed at about 20 minutes.

Automatic controls, set by an operator as the tested engine moves off the merry-go-round, take the engine automatically to one of three balancing stations, or to adjustment, then on to storage or shipping.

Here is another example of efficient production, paced and maintained by an MHS designed and built automatic system.

For most expert help in automation and automatic handling, call in the MHS engineer.

Mechanical Handling Systems Inc.

AND SUBSIDIARIES

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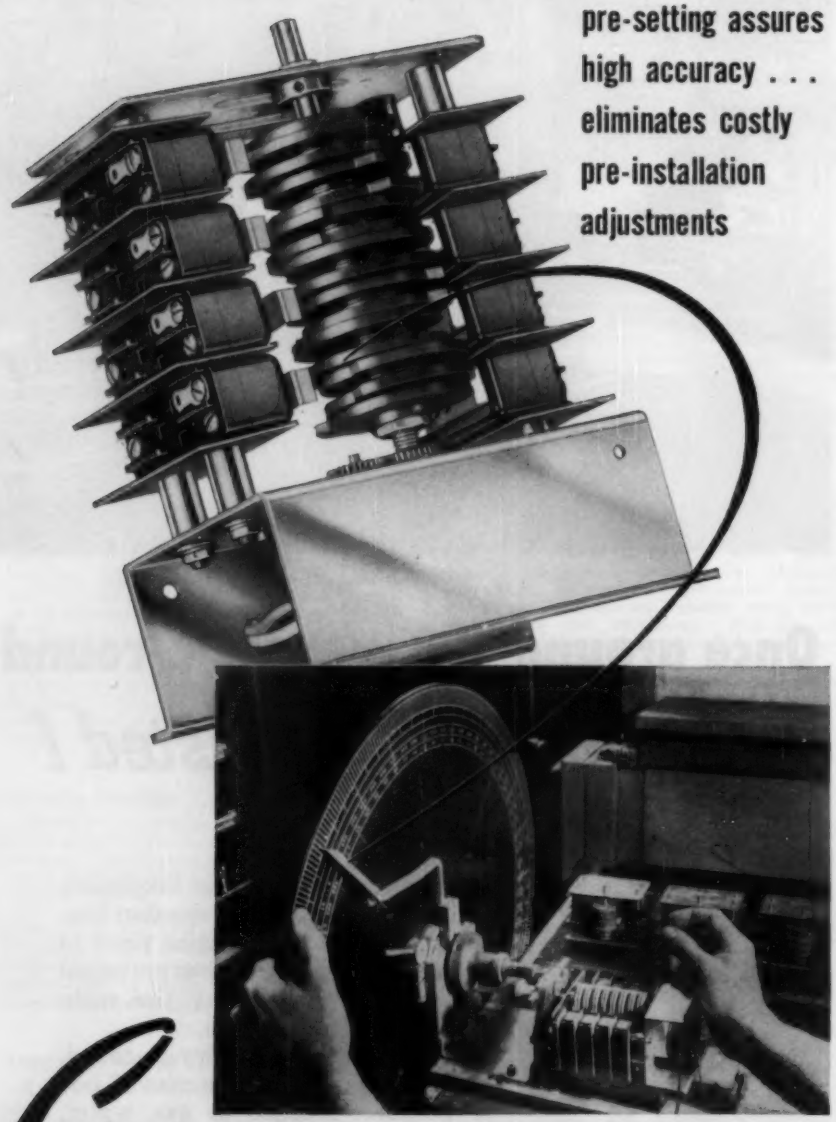
Factory pre-setting assures high accuracy . . . eliminates costly pre-installation adjustments



Cramer CYCLING TIMERS

The accuracy of a cycling timer depends on the exactness of the cam settings. If any one of the driving cams is incorrectly set, even to the minutest degree, the over-all program pattern or sequence of operations is changed.

Cramer cycling timers are normally supplied with all cams pre-set to customer specifications on special calibration equipment like that shown above. This pantographic principle, in effect, produces a sixteen-time enlargement of the cam, permitting extremely close setting accuracies.

While these timers can be adjusted in the field, factory setting assures highest accuracy and eliminates costly pre-installation adjustments.

This is but one of the many Cramer customer services designed to provide greater product usefulness and satisfaction at lower cost.

For full information about Cramer Cycling Timers, write for new Bulletin PB-510.

Cramer TIMING DEVICES

SPECIALISTS IN TIME CONTROL

The R. W. CRAMER CO., Inc.

BOX 35, CENTERBROOK, CONNECTICUT

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NEW CATALOGS

Machines for Automation

Barth Corp. — Designing, engineering and manufacturing skills of company are set forth in 38-page brochure. Among the designs for automatic equipment installations shown are assembly machines, control panels and dies. Also illustrated are lathes, jig borers, grinders, shapers, small and heavy tonnage presses, vertical boring mill, welders and reconditioners—used by company to produce equipment or production runs for customers. Photographs of departments in plant are included.

Circle No. 87 on Reply Card

Remote Controls

Trimount Instrument Co.—Five-page brochure discusses line of hydraulic positioning devices for hydraulic valves, winches, marine engine controls, charging cranes, slitting machines, butterfly valves and other remote control uses. Advantages of these units are listed. Diagrams illustrate cylinder assembly, compensating valve and reservoir. Specifications and applications of controls are included in the brochure.

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Servo Systems and Components

Feedback Controls Inc.—Collection of brochures on standard servo systems and components. Among equipment covered is dc instrument servo amplifiers, electronic servo systems, operational amplifiers, booster amplifiers, and magnetic servo amplifiers. Photographs of all equipment are included, along with specification and operational data on various models.

Circle No. 89 on Reply Card

Enclosure System

Elgin Metalformers Corp.—Four-page brochure discusses modular enclosure system which can be used as a basic console assembly, triple unit control console, or stacking cabinet. System is designed for enclosure applications in medical, computing, research integration, transmission, supervisory data, remote facsimile, radio and television equipment. Unit is of heavy gage steel all welded construction. Photographs of modular enclosure system and other company manufactured products are included.

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Packaging Booklet

Gerrard Steel Strapping Div., U. S. Steel Corp.—Thirty-six page booklet contains history of steel strapping, technical data charts, application photographs and illustrations of round and flat steel strapping machines and accessories. Among accessories covered are cutters for round steel strapping, mobile dispensers, containers, corner clips, drive screws, nails, sealers and cutters for flat steel strapping, anchor plate threaders, dispensers for flat steel strapping and stake pocket protectors.

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Electronic Timers

Automatic Temperature Control Co. Inc.—Data sheet discusses electronic timers which are designed for short interval time control. Photographs illustrate timer, timer mechanism, plug in dial, and timer case. Diagrams give external wiring arrangements. Load action chart, internal schematic wiring diagram and sketch with dimensions are also included.

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Hydraulics in Industry

John S. Barnes Corp.—Hydraulic power units for use in mass production industry are discussed in eight-page brochure. Among components of hydraulic power units illustrated are piston feed pumps, gear pumps, rotoblade pumps, fluid control valves, hydraulic cylinders, oil filter and relief valve units. Photographs also show constructional features.

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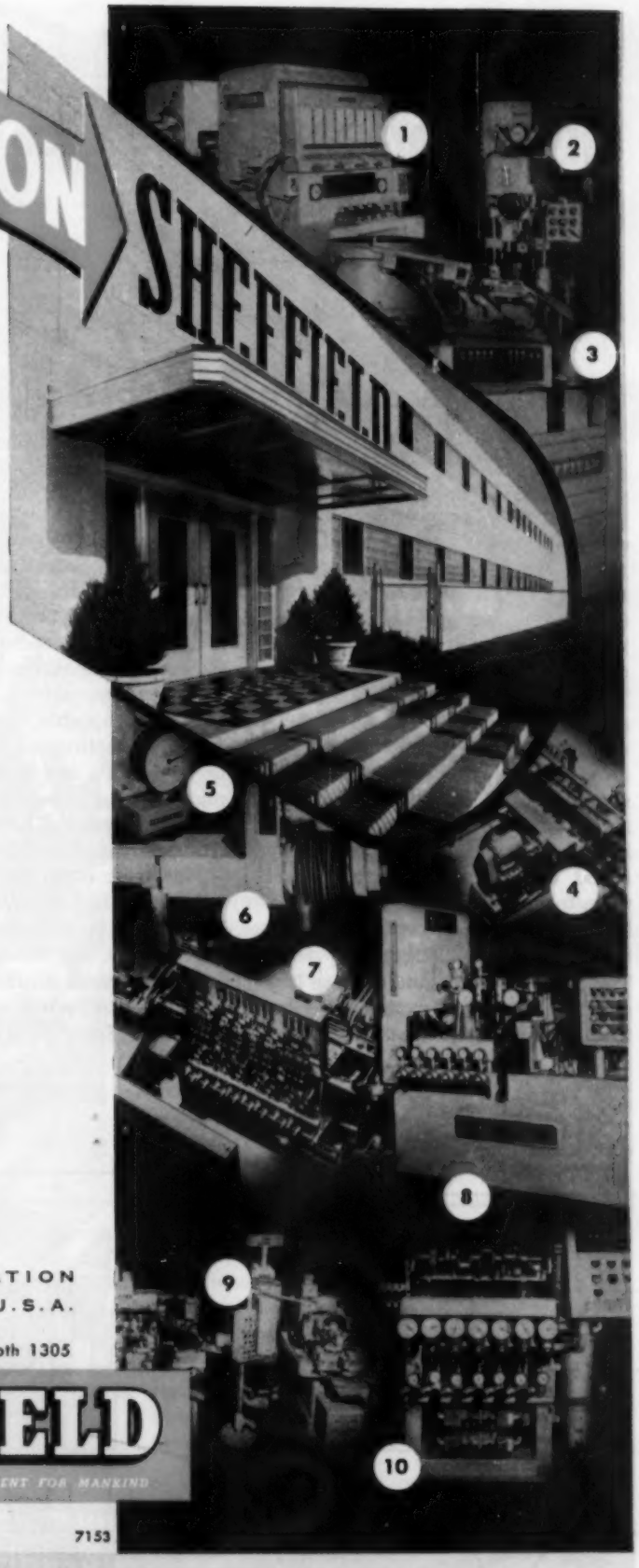

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AUTOMATION abstracts

TELEMETERING CUTS CONTROL COSTS

By L. G. WALKER and D. N. McMILLAN
Motorola, Inc.
Chicago, Ill.

POWER flow, generation, oil pressure, oil flow, bus voltage—all these values and many more are required for effective remote operation of substations, generating plants, pipe line pumping stations, tank farms, etc.

Most systems are actually installed with much less data provided to the remote operator than he would have if he were manning the station. This is strictly a matter of economics. If the comprehensive instrumentation normally found on a station control panel were to be duplicated by telemetering, most budget requests would never leave the engineer's desk. The industry needs and can use less costly telemetering systems. Therefore, a compromise must be reached between the data transmitted and the capital expenditure which can be justified. Selective telemetering is a key to this situation which should not be overlooked.

Certain telemetered data must, of necessity, be continuously received. Furthermore, only a minimum delay is acceptable in its full and final presentation. Channels for these signals are best provided by multiplexing the communication media established between the control point and the remote station.

However, other data are needed only at the operator's request. These may be periodic readings for log records, for investigations following various alarms, or for information to permit adjustments to be made. Such data are best provided by selective telemetering or interrogative measurement.

Selective telemetering provides many economies by permitting:

1. Shared use of the telemeter communication channel, thereby minimizing the cost of multiplexing equipment. This also reflects a reduction in bandwidth consumed or a reduction in the cost of leased line facilities.
2. Shared use of telemeter instrumentation. This item is probably the most important as it constitutes the major item of cost.
3. Shared use of sensing devices. This is particularly useful where electrical quantities may be conveniently switched.
4. Reduction in space through use of less apparatus.
5. Reduction in maintenance cost also by virtue of less equipment to maintain.

While not strictly economic factors, additional assets of selective telemetering are:

1. More efficient remote operation by making more effective use of the highly trained men at the control point.
2. Greater ease of channel supervision since fewer channels are required.
3. Telemeter selection which may be programmed to obtain quantities of data without manual supervision while still achieving the economies of shared equipment use.

In planning a typical system, several factors must be given careful consideration:

1. Use to which the data are to be put.
2. Instrumentation requirements and limitations.
3. Method to be used to switch the various quantities.

Where many quantities are to be read in rapid succession, where system adjustments are to be based on

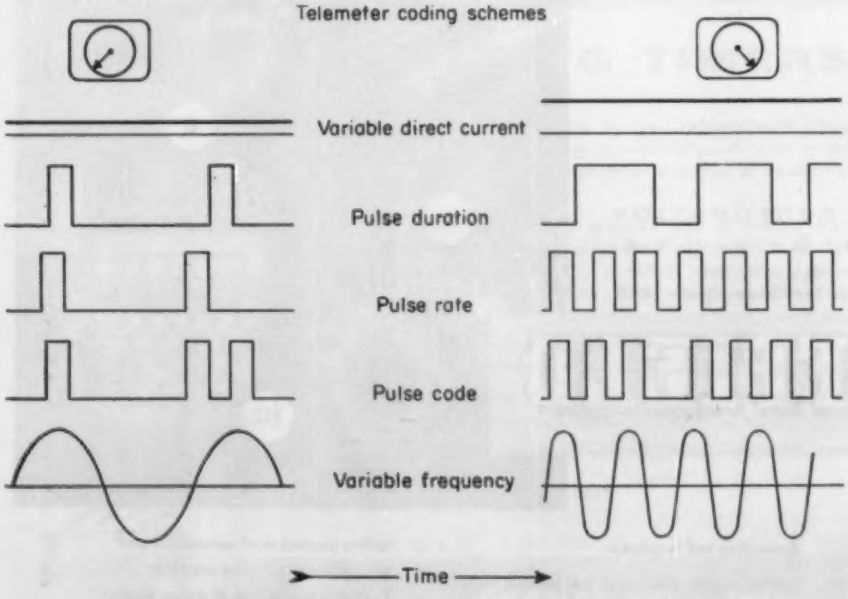


Fig. 1—Various telemetering coding schemes based upon the use of variable subaudio frequencies. These codes may be used to advantage where high speed telemetering must be applied

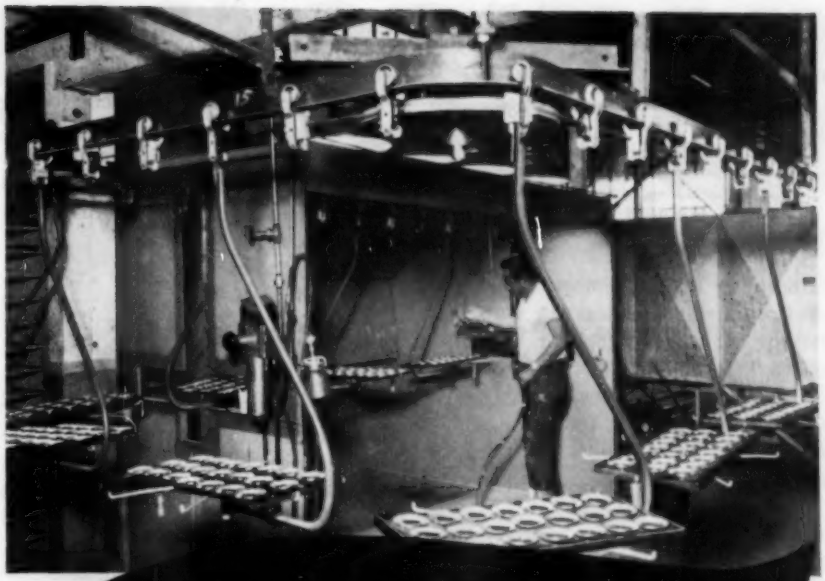
telemetered data, or where trouble is to be localized by data obtained, high speed telemetering must be applied. Coding schemes based on variable subaudio frequencies are excellent for this purpose, *Fig.* 1. Data of this type require rapid correction to be effective. Otherwise, the operator cannot make intelligent adjustments without long waiting periods to check the magnitude of correction needed.

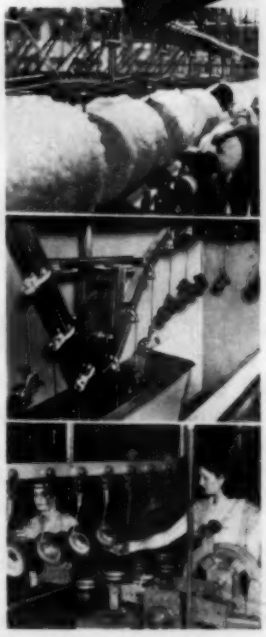
Where hourly readings must be taken and recorded, a long telemeter correction cycle can be most annoying to the operator. If the indication is being used to localize system trouble, any but the highest speed coding systems may completely miss the disturbance. For such purposes, the cost of higher speed devices can be easily justified, especially in light of the improved utilization through shared use.

Another use is the longer term monitoring of a quantity to determine a trend. This closely resembles continuous telemetering but is not truly so since the same equipment may be used to graph many similar variables by automatic programming of the telemeter switching. Where many similar quantities are desired and variation is sufficiently slow, the longer correction cycle is entirely adequate. A group of temperature readings is an excellent example. In other instances, a single quantity may be desired over a period of time, but the desired measuring point may change with the time of day, from day to day, or with various system conditions. A single telemeter system and recording device may by switched at will, whereas it would not be economically feasible to provide complete instrumentation of all data simultaneously. For such systems, pulse rate or pulse deviation coding is frequently chosen.

The quantities to be measured, the sensing elements available for this measurement, the restrictions imposed by circuit details, and the compatibility of the various readings all govern system layout.

Perhaps the simplest application involves a number of similar quantities capable of being switched into one telemeter transmitter and read or recorded on one telemeter receiver, *Fig.* 2. Voltage on a com-





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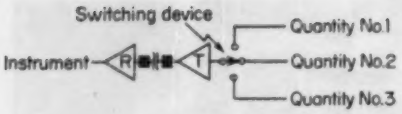

Fig. 2—By means of a switching device, a single communication channel can be used to telemeter a number of similar quantities measured by different instruments

mon base at various points in a station, temperatures at various points in a machine, or current on various lines are good examples. In this case, joint use of the communication channel and all instrumentation can achieve maximum economy.

Where it is impractical or impossible to directly switch the measured quantity, the same effective use is provided by associating a sensing element with each quantity and switching sensing element outputs.

Where it is impossible or impractical to switch current circuits, a system such as that shown in *Fig.* 3 is frequently utilized. Such a system provides joint use of the telemetering channel and may use a single set of receiving and indicating or recording instruments if adequate scale compatibility exists between the various quantities. Such systems are common in the power utility field where supervisory control is used to operate a major substation.

Any combination of selective telemetering schemes may be applied in a particular system, *Fig.* 4. Supervisory control can provide coordinated switching at each end of such a system so that the proper receiving instrumentation is always associated with the proper transmitting instrumentation.

Question and Answer Type

Interrogative measurement is a special type of selective telemetering characterized by an interrogation and answer type of operation. Contrary to the methods of the previous discussion, the answer in this type of system is a single measurement rather than the establishment of a continuously varying indication which continues until cancelled. Interrogative measurement systems usually use telemetering coding of the pulse code type. The measurement may be received on indicating dials, a cyclometer counter, or by teletypewriter presentation.

Typical examples are the interrogative measurement of tank levels, the indication of kilowatt hours consumed during a previous time interval or the temperature at a point at the time of interrogation, the quantity of units passing a measuring point in the system during a previous time interval, river flow data, or snow level data.

Frequently, the interrogative measurement system contains the selection or interrogating function as part of the overall coding scheme. A code is established and transmitted to the remote location. Reception and decoding initiate the transmission of the proper return code containing the identification of the measuring point and the desired measurement. Following the receipt of these data, the system is reset until a subsequent request is initiated.

Supervisory Control

Supervisory control is the most universally adapted switching media for selective telemetering and may also provide the interrogation function for interrogative measurement systems. It can be adapted to any selection scheme and any type of instrumentation.

Application generally falls into three basic categories. First, supervisory control is used to connect the telemetering instrumentation in the same fashion as it would be used to open and close a circuit breaker or other device. A full supervise and control point is required for this operation as well as a complete set of interposing

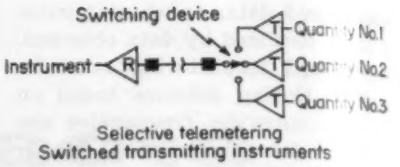

Fig. 3—When it is impractical to switch current circuits, transmitting instruments can be switched so that only one channel and a single set of receiving and indicating or recording instruments need be used

relays. Latching-type interposing relays are normally employed so that the telemetering selection will be retained until cancelled by an open request from the supervisory equipment. This scheme is used where telemetering is to be placed in operation and observed while the operator performs control functions on other points of the supervisory control system.

An additional special facility may be provided by the supervisory control in this type system. Where the telemetering transmitter has limit alarm contacts, this contact information may be made to appear in place of the usual open and close device position. The supervisory control may also be used to provide automatic alarm of abnormal conditions requiring observation of the telemetering data.

In a system layout where the telemetering is closely associated with a device being controlled by the system, a saving in supervisory control equipment can be achieved. When a point is selected to initiate control of the specific device, the telemetering associated with this measuring point is simultaneously placed into operation. It is obvious that this is a feature which only a select-before-operate supervisory control system can provide. Following this selection, the telemetering output may be observed

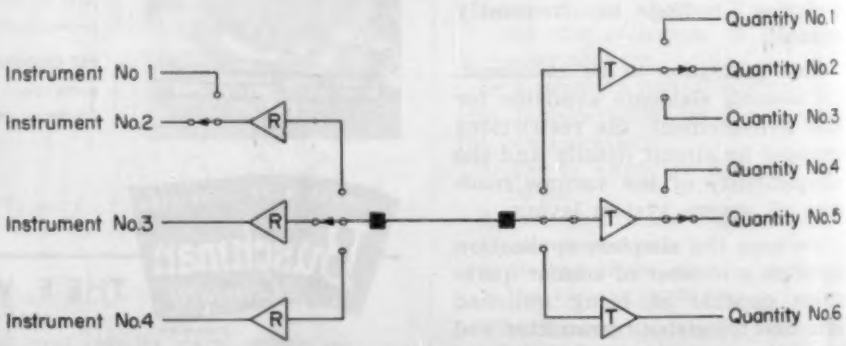

Fig. 4—Any combination of selective telemetering schemes can be applied in a particular system. This arrangement combines systems previously mentioned

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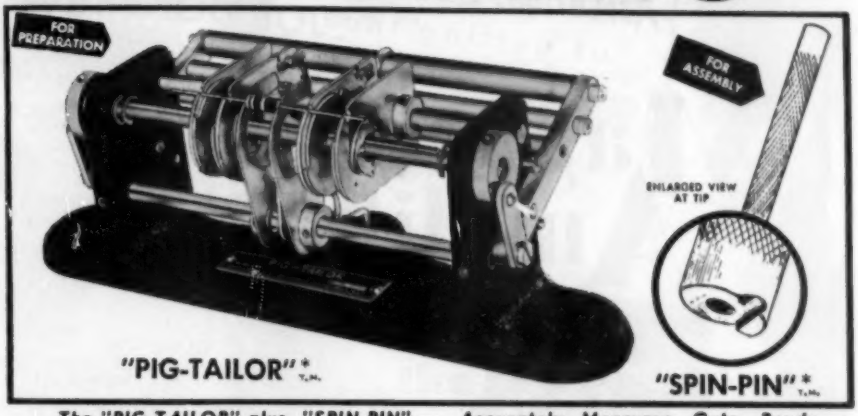

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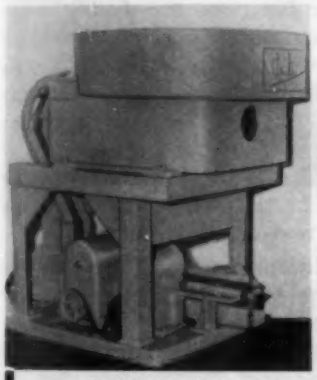

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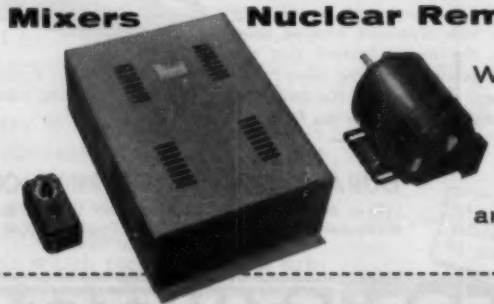

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for any desired period and then cancelled. Alternatively, the operator may open and close the device while observing the telemetering output. The addition of a telemetering function in this fashion in no way limits the supervisory control equipment and actually, in this arrangement, enhances the overall performance.

When considering the use of supervisory control for telemeter selection, it is important that a supervisory control selection does not tie up the system. Indications of automatic operations at the remote station must still be received immediately, even though the point selection associated with the telemetering is in force.

The point selection relays at both the master and remote station may be employed to switch the telemetering instrumentation so that the proper transmitting and receiving units are always properly associated.

In an expansion of the previous system, additional master functions are added to the supervisory control system to modify the telemetering quantity without changing the measuring point. Up to ten master functions are readily available, and once the selection feature has been used to determine the telemeter measuring point, these may be used in a wide variety of ways to connect the particular quantity to be measured or the particular phase of the system in which the measurement is to be made.

Additional master function keys may be momentary press type or may be arranged so that the particular indication will appear on the telemetering instruments for as long as the master key is pressed. Such master functions can, of course, be used to perform additional selections on any point in the supervisory control system so established.

Telemetering apparatus and modern supervisory control equipment can augment each other to expand the range of influence of operating personnel and increase the amount of data available to these people with very little increase in cost. Such additional data make possible co-ordinated action on the part of these people. In performing this service, selective telemetering conserves communication channels,

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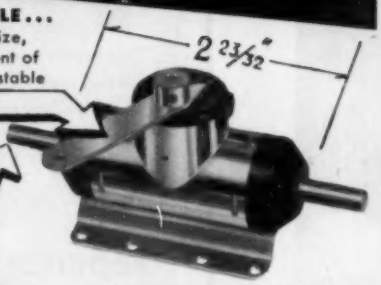

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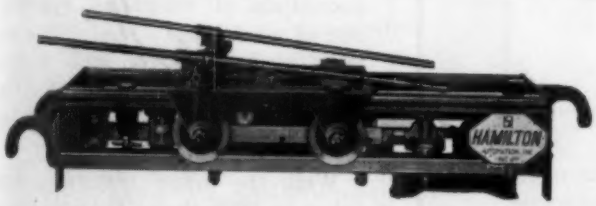

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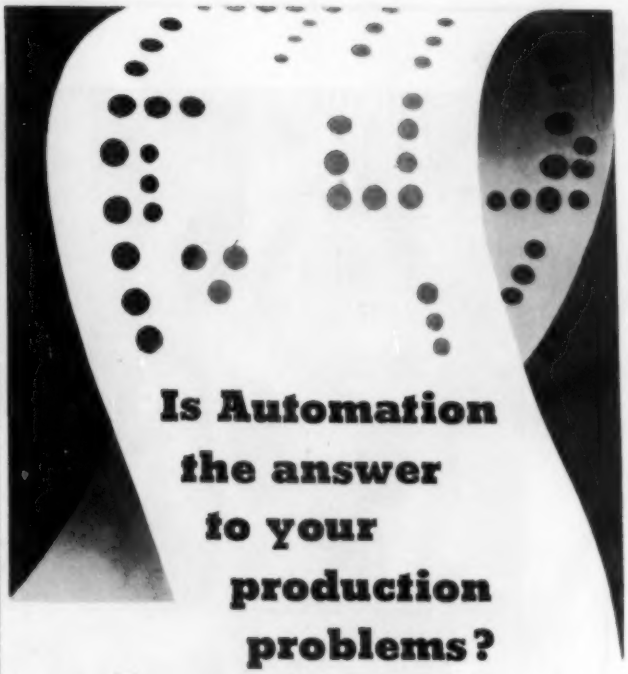

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From a paper entitled, "Selective Telemetering Applications" presented at the National Telemetering Conference, May 1954.

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United States Steel Corp.
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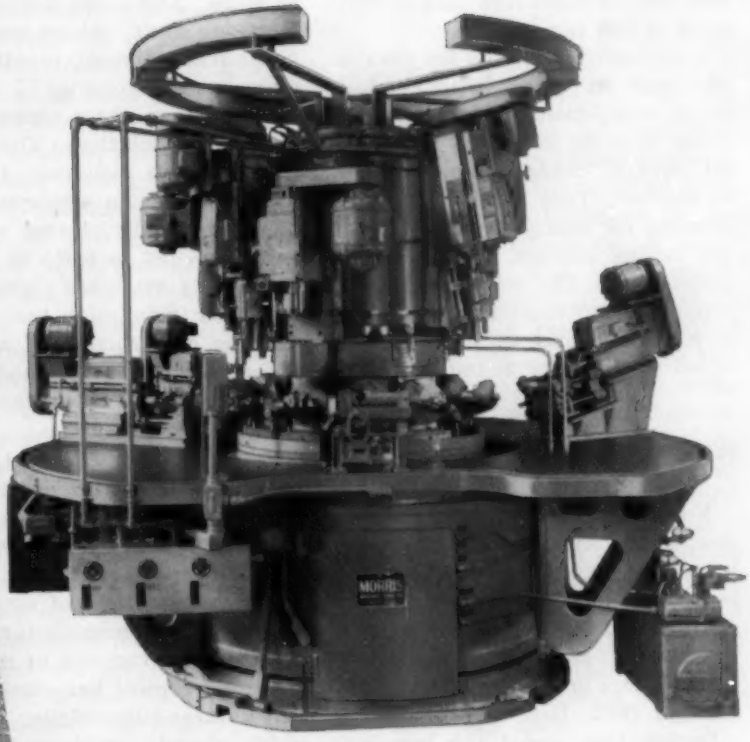

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the auto industry it is estimated that five new jobs are created in allied fields which supply the raw materials and components that go into the manufacture and equipment of new cars.

But this, of course, is not always the case in every industry and every occupation. Dislocations do occur in some instances, and men do have to change from one job to another. That has been true in farming for nearly 40 years. With the falling demand for coal, employment in the mines has also dropped off substantially, and there is recent evidence of mild decline in oil refining, for example.

What Are the Facts

Now where are these displaced men to go? Has automation made it tougher for them than it used to be? Let's look at the picture as a whole and see for ourselves just what really has happened in the last 15 years or so—say from 1939 through 1953. Here are the facts.

During this period the population of the United States has increased 22 per cent. But the total number of jobs has grown by 35 per cent—or more than half again as much. And in the field of manufacturing itself—where automation has advanced most rapidly — employment has gone up 73 per cent, or more than three times as fast as the population. The record clearly shows moreover, that this rapid increase in employment has occurred chiefly because of mechanization—not in spite of it. The building of machines themselves—plus their installation, maintenance and the construction of new factories to house them—has opened thousands of job opportunities that never existed before.

Employment in the field of electrical machinery, for example, has more than trebled during this period. In other machinery it has increased by 150 per cent. And in the specialized field of automation itself, the mere manufacture of the necessary instruments of measurement and control has mushroomed into a three-billion-dollar business which already employs as many men as the auto industr did in the middle 1930's.

But that is only the b ginning. As mechanization has enl ged the output and the purchasing ower of our people, it has also m ltiplied enormously their demand or services. So they, in their turn employ more doctors and dentists, more engineers and scientists, and more teachers and clergymen. They send out more of their laundry, and they eat more often in restaurants. Even the fact that they have more leisure time has created more jobs for others. Employment in tourist courts and camps has more than tripled. Theatres, movies, amusement parks and similar establishments provide 75 per cent more jobs than formerly. The purchase of books has doubled, and expenditures for home music have trebled. And so it goes. Employment in the service industries alone has risen by more than two million during these 14 years. And that is a jump of 65 per cent.

The same thing has happened, too, in the general field of trade. As the volume of production has

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increased, it has taken more workers to sell and to handle these goods. And thus, six million new jobs have been opened up by the growing employment demands of department stores, shops, offices, builders, bankers, utilities, bus lines, trucking companies, and others in this category.

And finally, of course, our advance in technology has created whole new industries, and vast new fields of opportunity, in television, antibiotics, air conditioning, many new branches of electronics, and now, in atomic energy—just to mention a few. So with each passing year, and with every new invention, our people have a wider choice of jobs; and today, it is reported that there are more than forty thousand different ways whereby Americans can earn a living!

But suppose, for example, that all technological progress in the auto industry had stopped back in 1908, and that we were to try to build a 1955 car, at today's wages, with the tools and machines we used then. Such a car, if it could be produced at all, would cost well in excess of $65,000! How many cars would there be on the road? And how many roads would we have? How many jobs would there be in Detroit, and in the oil fields, and in the tire-making industry—or even in our steel mills for that matter? Why, millions of our workers would be idle, and America would rank among the so-called backward nations of the world—provided, of course, that we had been able to survive at all as a free and independent people.

So the time has come, I think, to nail this vicious propaganda for the miserable fraud that it is. The facts show that only through the widest possible use of new and better machines can we hope to achieve the fullest measure of employment and a higher standard of living.

And while we are at this business of nailing, let's tackle another dangerous deception that the busy propagandists are perpetrating these days: that is the charge that the greedy owners of industry have grabbed the lion's share of the fruits of technology, while the workers have been robbed of the rightful rewards of their mounting, mechanized production.

Who Benefits

Now fortunately, the true facts of this matter are readily available in a study which was made by Allen W. Rucker, and published by the Eddy-Rucker-Nickels Co. of Cambridge, Mass. This study covers the 33-year period from 1914 to 1947—a whole generation during which the two great wars of this century were fought, and when American industry was undoubtedly making some of the most important and fundamental technological progress in its history. Moreover, Mr. Rucker's analysis is based entirely on the United States Census of Manufacturers and other official government reports; so I do not suppose that anyone will challenge the authenticity of the facts which he presents. And this is what they show.

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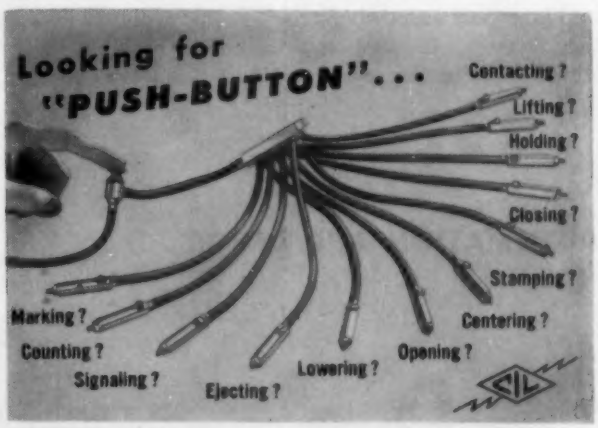

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basis, over this entire period, the output of the men and machines in American manufacturing as a whole increased by 161 per cent; that the real wages of the workers, measured in terms of purchasing power, increased 157 per cent, and that the relative prices of manufactured products, measured in terms of hourly wages, declined 61 per cent.

In its findings, therefore, the report states that the real wages of the worker have advanced "at almost exactly the same rate as the improvement in productivity." It adds that under the American system of manufacturing, the advance in such wages "depends wholly upon advances in productivity." And it declares, in conclusion, that the manufacturing industry on the whole has passed on to its customers and employees "virtually all the 'savings' from increased productivity"—that rarely, and only temporarily, have the owners retained any gains whatever from this source.

And in further support of Mr. Rucker's statements, I should like to call your attention to one additional fact which is not contained in his report: that back in 1914, the share of the national income which went to the owners of business in the form of dividends was about six per cent; but in 1947, their share amounted only to about three per cent. So over this 33-year period, the owners who put up the money for all the machines that made increased production possible, found that their slice of our total economic pie had been cut approximately in half.

It may well be asked, of course, why industry continues to spend billions of dollars upon the development and purchase of improved machines if its owners receive no direct gains from these expenditures. And the answer to that, as we know, is all bound up in one simple word—competition.

Progress or Perish

I shall conclude my argument by quoting the words of two famous Americans, who came from different walks of life, but who knew and understood this question.

One of these men was a great labor leader who was often my adversary, but always, I think, my friend. His name was Philip Murray; and standing before a convention of the CIO, not many months before his unfortunate death, he said, "I do not know of a single, solitary instance where a great technological gain has taken place in the United States of America that it has actually thrown people out of work. I do not know of it—I am not aware of it—because the industrial revolution that has taken place in the United States in the past 25 years has brought into the employment field an additional 20 million people."

That statement, of course, was both wise and true; and I earnestly hope it will always live on in the hearts and the minds of American labor.

And as for my other quotation, it comes from a man who spent much of his life on the management side of the fence. His name was Wendell Willkie; and during the autumn of 1940, not many months before Pearl Harbor, he stumped the length and the breadth of this land, repeating at every whistle-stop his solemn and prophetic warning, "Only the productive can be strong; and only the strong can be free!"

From an address entitled, "Our One Indispensable Weapon" presented at the annual dinner of the Greater Johnstown Chamber of Commerce in Johnstown, Pa., Feb. 1955.

AUTOMATION AND LABOR

By A. ABRUZZI
Stevens Institute of Technology
Hoboken, N. J.

WHAT SEEMS to be labor's viewpoint on automation? The fact of the matter is that there is no labor viewpoint, at least no crystallized labor viewpoint. One can only cull certain feelings expressed by labor people and see what they imply.

Those directly affected by automation do have something of a viewpoint, if undisciplined feelings can be considered to reflect a viewpoint. These feelings can be summed up in a word—anxiety. Those who work in the Ford Dearborn Engine Plant, for example, are in something of a state of anxiety. The local union is likewise in a state of anxiety. These people are anxious about their job security and status, and the local union mirrors the anxiety and projects it to cover other groups in its membership.

Information about job security and status moves rapidly. If workers are displaced in one part of a plant, the feeling develops that perhaps the same thing will happen in other parts of the plant. The Dearborn Steel Mill, for example, has also been modernized in line with the automation approach. The result is an ever-widening anxiety reflecting concern over what and who will be affected next.

Now, of course, there can be no labor policy because there is no labor viewpoint. There are statements about what should be done in the immediate situation. One hears, for example, that the workweek should be shortened. This is clearly an attempt to stabilize the work force at much the same size as it was before automation. These statements relieve the anxiety somewhat because they are hopeful; they do not eliminate the anxiety because they are only hopeful.

This is not at all surprising. Planning the role of labor has always been the most challenging problem of fitting new technologies into a civilization. The fact is that social viewpoints are rarely, if ever, revised according to timetable despite the desperate efforts of scholars in academic robes

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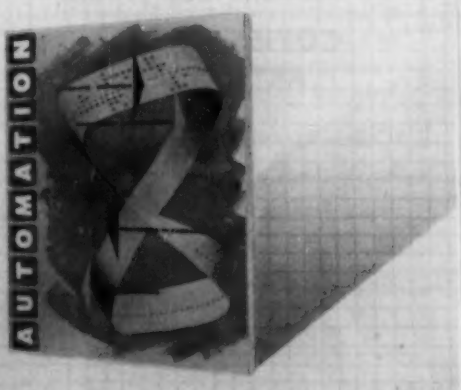

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and on platforms. Social viewpoints usually change only when direct pressures are exerted upon the groups concerned which then devise solutions for the immediate problem.

Perhaps the society is wise to ignore the blandishments of scholars. But the society is not wise to ignore itself. To be sure, there are always problems of everyday living that seem to require immediate attention. But isn't this the same as saying that long-range planning is one of the most difficult and unrewarding processes known to man? People cling to a viewpoint until it is no longer a viewpoint with meaning, and then they scurry about looking for a new viewpoint.

Official Views

What else can be discerned about labor's feelings? How about those who are somewhat more remote from the immediate situation, the people who staff central union offices? They, of course, do not have any personal anxiety so they do not grope for a local solution. They appear to be more concerned with broader aspects of automation, always keeping in mind, of course, the problem of how many union members will be lost and what can be done about it.

One result is that automation committees have been created in some cases; these committees apparently consult with workers, social scientists and history. These consultations tell them that automation is going to be a fact of life and so these committees say that labor accepts the concepts of automation and also the practice of automation. This acceptance must be dignified by a social stance so they say, too, that labor does not intend to stand in the way of progress.

In the past labor's strategy was to slow down technological progress so that it wouldn't inhibit labor's then current vested interests. The present attitude may, ultimately, not be too distant from the past attitude but it does admit, perhaps reluctantly, that labor objectives must be fitted to general social objectives.

In a few cases the statements also say that labor will have to have its full share in the fruits of automation, although the mechanism for achieving this is expressed in nebulous terms. The statements offered, then, refer to general goals rather than to their implementation. In no case has labor expressly considered the specific implications of automation.

There are also those in labor who feel that they will not be greatly affected by automation. They are quite willing to speculate about the problem, but only at a remote level. They are not unduly disturbed by automation because their unions and workers apparently will not be involved. They are quite willing to agree that automation is likely to change things. But automation is just another step in the continual movement toward a more complicated technology. Much like a classical economist, they can afford to take the lofty view that automation will eventually create more wealth and let it go at that.

This quite covers the story of articulated feelings and views. These views are clearly not well thought out. Labor has had only local glimpses of automation, such as in automobile engine plants. Also, probably not unlike management, labor is primarily interested in day-to-day problems. Institutional survival dictates that labor unions keep operating this way since most of their workers, like machines, are still evaluated directly in terms of units produced.

It seems, however, that this philosophy must be overhauled if heavy social costs are to be avoided. For this labor ought to become educated about automation, which is not the same as saying that someone ought to educate labor. True, labor might be educated by engineers about the technical aspects of automation. But labor itself should make a distinct contribution to the educational process by defining its goals and suggesting courses of action to the society, to be considered along with those suggested by management.

Automation will bring about a production system in which workers will be external to the system. Trivial production tasks will be transferred to machines—final

proof that the tasks in question are indeed trivial. There is really nothing new in the drudgery of work. The only factor introduced by the modern industrial technology is an awareness that many more jobs can be classified as trivial. This is precisely why workers have been able to obtain sufficient time and material goods so that they needn't be drudges away from the workplace. Thus the industrial society is solving the problem of drudgery by assigning the drudgery to machines. Characteristically, tired social scientists fail to recognize that it was necessary to trivialize production tasks in order to bring this situation about. The answer, then, is to build on what exists to eliminate what is undesirable, not to destroy what exists and eliminate what is desirable as well as what is undesirable.

A worker will then become nonproductive, but only in the sense that he will no longer be evaluated directly in terms of units produced. He will be external to the production activity but he will be its controller. This will require technical and intellectual skills vastly greater than those now required of production workers. The status of a worker will be greatly enhanced, if only because he is no longer competing with machines for the privilege of doing trivial work whose worth can be measured in production units.

The other side of the coin is that drudgery and its operational counterpart, trivial tasks, are espoused by many workers. These workers like trivial tasks precisely because these tasks make neither technical nor intellectual demands of them. These workers prefer to be instructed in detail about the set of work elements they are to perform and in what sequence. This frees them from personal responsibility and, of course, from vocational dignity, but they don't seem to mind this because responsibility and dignity require attention. Apparently the sacrifice of personal responsibility and dignity seems small in exchange for the privilege of spurious mental leisure.

From a paper entitled, "A Look at Automation from Labor's Point of View" presented at the ISA Automatic Plant Symposium in Philadelphia, Dec. 1954.

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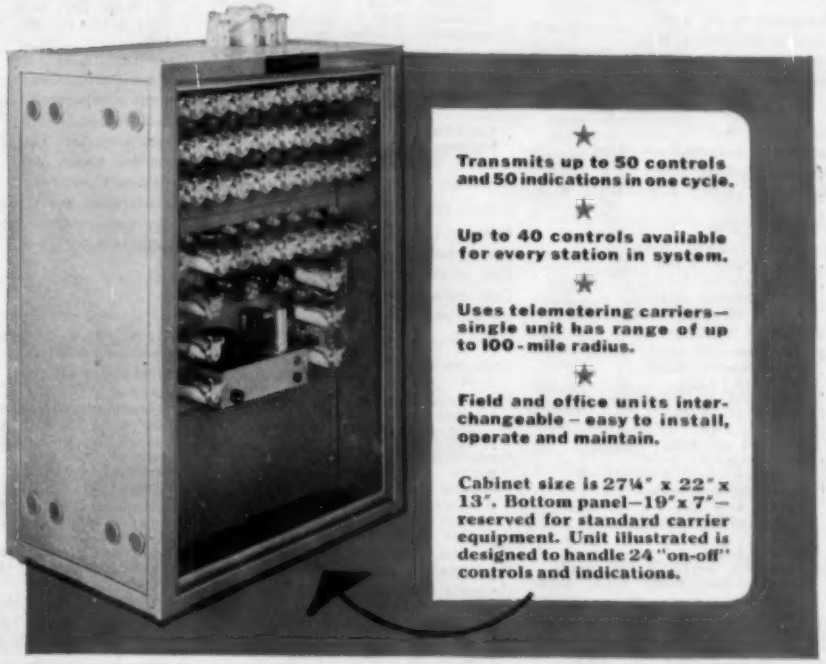
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By Andrew D. Booth, reader in computational methods, University of London; 195 *pages,* 5¼ *by* 8½ *inches, illustrated, clothbound, published by Academic Press Inc., New York; available from* AUTOMATION; $6.00 *postpaid.*

This book has been designed to cover the basic principles on which numerical analysis rests, and therefore does not stress details of actual calculation. This approach is particularly useful to those who are interested in the art of programming for automatic calculators and who need an understanding of the underlying mathematical principles to make effective use of the new tools which automatically carry out the details of calculation.

SERVOMECHANISMS AND REGULATING SYSTEM DESIGN, VOL. II

By Harold Chestnut and Robert W. Mayer, Aeronautics and Ordnance Systems Div., General Electric Co.; 384 *pages,* 5¾ *by* 9 *inches, illustrated, clothbound, published by John Wiley & Sons Inc., New York; available from* AUTOMATION; $8.50 *postpaid.*

An up-to-date coverage of many phases of the feedback control system art, providing practical design methods for the solution of servomechanism and regulating systems problems. This volume is written for the practicing designer and the advanced graduate student. The design steps required to work from the control system parameters to suitable hardware specifications are stressed so that dependable, serviceable equipment can be obtained.

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By Harry Aubrey Toulmin Jr.; second edition, 929 *pages,* 6 *by* 9 *inches, illustrated, clothbound, published by the W. H. Anderson Co., Cincinnati; available from* AUTOMATION; $15.00 *postpaid.*

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Government Publications

Computer Development (SEAC and DYSEAC) at the National Bureau of Standards. *National Bureau of Standards Circular* 551, 146 *pages, illustrated, available from Government Printing Office, Washington* 25, *D. C.;* $2.00.

Presents important engineering aspects of the Bureau's electronic computer program mostly related to experience in designing, constructing, and operating two high-speed, automatically sequenced, electronic digital computers. Extensive use was made of germanium diodes for switching and gating with mercury delay-line internal memories and an additional electrostatic memory.

Summary of Joint Nomenclature System ("AN" System) for Communications-Electronic Equipment. *Report PB* 111581 *by Joint Communications-Electronic Committee;* 2 *pages; available from Office of Technical Services, U. S. Department of Commerce, Washington* 25, *D. C.;* 25 *cents.*

Handy chart summarizes the co-ordinated system of nomenclature for communications-electronic equipment used by the Department of Defense. The chart sets forth and briefly explains the alphabetical-numerical system used to assign type numbers to items of communications-electronic equipment and components. The coding system indicates the type of equipment, where it is normally installed, and its functional purpose.

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Paperbound, 28 *pages,* 6 *by* 9 *inches; available from American Management Association,* 330 *West* 42*nd St., New York* 36, *N. Y.;* $1.50.

Report on a survey made by AMA's Management Information Service in the spring of 1954 to determine current personnel practices in both individual and mass transfers and relocation. Tabulations of questionnaire returns are given outlining number of respondents assisting employees in transfers, types of assistance and cost of assistance.

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